F-35 Joint Strike Fighter (JSF)

Executive Summary

Test Planning, Activity, and Assessment

- The program focused on culminating Block 2B development and testing in order to provide a fleet release enabling the Marine Corps F-35B Joint Strike Fighter (JSF) declaration of Initial Operational Capability (IOC), while transitioning development and flight test resources to Block 3i and Block 3F.
  - The program terminated Block 2B developmental flight testing in May 2015, delivering Block 2B capability with deficiencies and limited combat capability. The Marine Corps declared IOC at the end of July 2015. However, if used in combat, the Block 2B F-35 will need support from command and control elements to avoid threats, assist in target acquisition, and control weapons employment for the limited weapons carriage available (i.e., two bombs, two air-to-air missiles). Block 2B deficiencies in fusion, electronic warfare, and weapons employment result in ambiguous threat displays, limited ability to respond to threats, and a requirement for off-board sources to provide accurate coordinates for precision attack. Since Block 2B F-35 aircraft are limited to two air-to-air missiles, they will require other support if operations are contested by enemy fighter aircraft. The program deferred deficiencies and weapons delivery accuracy (WDA) test events from Block 2B to Block 3i and Block 3F, a necessary move in order to transition the testing enterprise to support Block 3i flight testing and Block 3F development, both of which began later than planned in the program's Integrated Master Schedule (IMS).
  - Block 3i developmental flight testing restarted for the third time in March 2015, after two earlier starts in May and September 2014. Block 3i developmental flight testing completed in October, eight months later than planned by the program after restructuring in 2012, as reflected in the IMS. Block 3i began with re-hosting immature Block 2B software and capabilities into avionics components with new processors. Though the program originally intended that Block 3i would not introduce new capabilities and not inherit technical problems from earlier blocks, this is what occurred. The Air Force insisted on fixes for five of the most severe deficiencies inherited from Block 2B as a prerequisite to use the final Block 3i capability in the Air Force IOC aircraft; Air Force IOC is currently planned for August 2016 (objective) or December 2016 (threshold). However, Block 3i struggled during developmental testing (DT), due to the inherited deficiencies and new avionics stability problems. Based on these Block 3i performance issues, the Air Force briefed that Block 3i mission capability is at risk of not



meeting IOC criteria to the Joint Requirements Oversight Council (JROC) in December 2015. The Air Force recently received its first Block 3i operational aircraft and is assessing the extent to which Block 3i will meet Air Force IOC requirements; this assessment will continue into mid-2016.
  - Block 3F developmental flight testing began in March 2015, 11 months later than the date planned by the program after restructuring in 2012, as reflected in the IMS. Progress has been limited (flight testing has accomplished approximately 12 percent of the Block 3F baseline test points as of the end of November) as the program focused on closing out Block 3i testing and providing a software version suitable to support plans for the Air Force to declare IOC in August 2016.
- The current schedule to complete System Development and Demonstration (SDD) and enter IOT&E by August 2017 is unrealistic.
  - Full Block 3F mission systems development and testing cannot be completed by May 2017, the date reflected in the most recent Program Office schedule, which is seven months later than the date planned after the 2012 restructure of the program. Although the program has recently acknowledged some schedule pressure and began referencing July 31, 2017, as the end of SDD flight test, that date is unrealistic as well. Instead, the program will likely not finish Block 3F development and flight testing prior to January 2018, an estimate based on the following assumptions:
    - Continuing a six test point per flight accomplishment rate, which is equal to the calendar year 2015 (CY15) rate observed through the end of November.

- Continuing a flight rate of 6.8 flights per month, as was achieved through the end of November 2015, exceeding the planned rate of 6 flights per month (note that if the flight rate deteriorates to the planned rate of 6 flights per month, then testing will not complete until May 2018).
- Completing the full Block 3F test plan (i.e., all 7,230 original baseline and budgeted non-baseline test points in the Block 3F joint test plan).
- Continuing the CY15 discovery rate of 5 percent, i.e., 5 additional test points are required to address new discoveries per 100 baseline test points accomplished. This assumption is optimistic. In the likely event significant new discoveries continue during developmental testing in 2016, additional Block 3F software releases would be needed to address them, adding more test points and extending development further.

- The program could, as has been the case in testing previous software increments, determine that test points in the plan are no longer required for the Block 3F fleet release. However, the program will need to ensure that deleting and/or deferring Block 3F testing before the end of SDD and start of IOT&E does not result in increasing the likelihood of discovery of deficiencies in IOT&E or degrading F-35 combat capability. Whatever capability the program determines as ready for IOT&E will undergo testing fully consistent with the Department's threat assessments, war plans, and the Services' concepts of operation.

- The program has proposed a "block buy" that commits to and combines procurement of three lots of aircraft to gain savings. Executing the "block buy" would require commitments to procuring as many as 270 U.S. aircraft, as well as commitments by foreign partners to purchasing substantial numbers of aircraft. Depending upon the timing, it is possible a commitment to the "block buy" would be made before operational testing is complete. In that case, entering a "block buy" would raise the following questions:
  - Is it premature to commit to the "block buy" given that significant discoveries requiring correction before F-35's are used in combat are occurring, and will continue to occur, throughout the remaining developmental and operational testing? The program continues to struggle with Block 3F developmental testing, and in December 2015 the Air Force rated its proposed initial operational capability supported by Block 3i as "red" due to the problems ongoing testing has revealed.
  - Is it prudent to further increase substantially the number of aircraft bought that may need modifications to reach full combat capability and service life? As the program manager has noted, essentially every aircraft bought to date requires modifications prior to use in combat.
  - Would committing to a "block buy" prior to the completion of IOT&E provide the needed incentives to the contractor and the Program Office to correct an already substantial list of deficiencies in performance, a list that will only lengthen as Block 3F testing continues and IOT&E is conducted?
  - Would entering a "block buy" contract prior to the completion of IOT&E be consistent with the "fly before you buy" approach to defense acquisition that many in the Administration have supported? Similarly, would such a "block buy" be consistent with the intent of Title 10 U.S. Code, which stipulates that IOT&E must be completed and a report on its results provided to Congress before committing to Full-Rate Production—a commitment that some could argue would be made by executing the "block buy?"

Helmet Mounted Display System (HMDS)

- The program tested the Generation III (Gen III) helmet-mounted display system (HMDS), which is intended to resolve all of the deficiencies discovered in the Gen II system in prior years. The Gen III system is a requirement for Air Force IOC in 2016; it will be the helmet used to complete SDD and IOT&E. After Gen III developmental testing, developmental test pilots reported less jitter, proper alignment, improved ability to set symbology intensity, less latency in imagery projections, and improved performance of the night vision camera. However, operational testing in realistic conditions and mission task levels, including gun employment, is required to determine if further adjustments are needed.

Mission Data Load Development and Testing

- The F-35 relies on mission data loads—which are a compilation of the mission data files needed for operation of the sensors and other mission systems—to work in conjunction with the system software data load to drive sensor search parameters and to identify and correlate sensor detections, such as threat and friendly radar signals. The U.S. Reprogramming Lab (USRL), a U.S. government lab, produces these loads for U.S. operational and training aircraft. Mission data optimization testing, which includes both lab-testing and flight-testing, is conducted by an Air Force operational test unit augmented by Navy personnel. The unit provides the test plans to the DOT&E for approval and independent oversight.
- Significant deficiencies exist in the USRL that preclude efficient development and adequate testing of effective mission data loads for Block 3F. Despite being provided a $45 Million budget in FY13, the program has still not designed, contracted for, and ordered the required equipment—a process that will take at least two years, not counting installation and check-out. In addition, despite the conclusions of a study by the Program Office indicating that substantial upgrades are needed to the laboratory's hardware, the program is currently only pursuing a significantly lesser upgrade due to budgetary constraints. This approach would leave the USRL with less capability than the F-35 Foreign Military Sales Reprogramming Lab. Unless remedied, these deficiencies in the USRL will translate into significant limitations for the F-35 in combat against existing threats.

The program must take immediate action to complete required modifications and upgrades to the lab before the USRL is required to provide the Block 3F mission data load for tactics development and preparations for IOT&E.

- After the program delayed the build-up of the USRL equipment and software tools, which created schedule pressure on Block 2B mission data load development and testing, the Program Office forced the USRL to truncate the planned testing, forgoing important steps in mission data load development in order to provide a limited mission data load in June 2015 for the Marine Corps IOC declaration in July 2015. Fielded operational units must take into consideration the limited extent of lab and flight testing that occurred—which creates uncertainties in F-35 effectiveness—until the USRL is able to complete development and testing of a Block 2B mission data load. This is planned to occur in early 2016.

Weapons Integration

- The program terminated Block 2B developmental testing for weapons integration in December 2015 after completing 12 of the 15 planned WDA events. The program planned to complete all 15 WDA events by the end of October 2014, but delays in implementing software fixes for deficient performance of mission systems sensors and fusion delayed progress. Three events were deferred to Block 3i (one event) and Block 3F (two events) developmental testing.
  - Eleven of the 12 events required intervention by the developmental test control team to overcome system deficiencies and ensure a successful event (i.e., acquire and identify the target and engage it with a weapon). The program altered the event scenario for three of these events, as well as the twelfth event, specifically to work around F-35 system deficiencies (e.g., changing target spacing or restricting target maneuvers and countermeasures).
  - The performance of the Block 2B-configured F-35, if used in combat, will depend in part on the degree to which the enemy's capabilities exceed the constraints of these narrow scenarios and the operational utility of the workarounds necessary for successful weapons employment.
- The Block 3F WDA events plan currently contains events that will test Block 3F capabilities to employ the GBU-12 Paveway II laser-guided bomb, GBU-31/32 Joint Direct Attack Munition (JDAM), Navy Joint Stand-off Weapon (JSOW)-C1, Small Diameter Bomb I (SDB-1), AIM-120C Advanced Medium-Range Air-to-Air Missile (AMRAAM), AIM-9X, and the gun in the full operating environment of each variant.
  - The Block 3F developmental test WDA plan contains 48 events in the approved Test and Evaluation Master Plan (TEMP), plus two WDA events deferred from Block 2B, for a total of 50. These 50 WDA events cannot be accomplished within the remaining time planned by the Program Office to complete Block 3F flight test (by May 2017, per the program's master schedule), nor by July 2017 (the most recent briefed date to complete Block 3F flight test from the Program Office), and support the date in the IMS for the Block 3F fleet release (August 2017). The past WDA event execution rate is approximately one event per month. The test team would need to triple this rate to complete all WDA events in the approved TEMP by May 2017. However, these Block 3F events are more complex than the Block 2B and 3i events.
  - In an attempt to meet the schedule requirements for weapon certification, the Program Office has identified 10 WDA events for the F-35A and 5 events for the F-35B and F-35C that must be accomplished during Block 3F developmental testing. The program still plans to accomplish the remaining 33 events, if schedule margin allows. The overall result of the WDA events must be that the testing yields sufficient data to evaluate Block 3F capabilities. Deleting numerous WDA events puts readiness for operational testing and employment in combat at significant risk.

Verification Simulation (VSim)

- Due to inadequate leadership and management on the part of both the Program Office and the contractor, the program has failed to develop and deliver a Verification Simulation (VSim) for use by either the developmental test team or the JSF Operational Test Team (JOTT), as has been planned for the past eight years and is required in the approved TEMP. Neither the Program Office nor the contractor has accorded priority to VSim development despite early identification of requirements by the JOTT, $250 Million in funding added after the Nunn-McCurdy-driven restructure of the program in 2010, warnings that development and validation planning were not proceeding in a productive and timely manner, and recent (but too late) intense senior management involvement.
- The Program Office's sudden decision in August 2015 to move the VSim to a Naval Air Systems Command (NAVAIR)-proposed, government-led Joint Simulation Environment (JSE), will not result in a simulation with the required capabilities and fidelity in time for F-35 IOT&E. Without a high-fidelity simulation, the F-35 IOT&E will not be able to test the F-35's full capabilities against the full range of required threats and scenarios. Nonetheless, because aircraft continue to be produced in substantial quantities (all of which will require some level of modifications and retrofits before being used in combat), the IOT&E must be conducted without further delay to evaluate F-35 combat effectiveness under the most realistic conditions that can be obtained. Therefore, to partially compensate for the lack of a simulator test venue, the JOTT will now plan to conduct a significant number of additional open-air flights during IOT&E relative to the previous test designs. In the unlikely event a simulator test venue is available, the additional flights would not be flown.

Suitability

- The operational suitability of all variants continues to be less than desired by the Services and relies heavily on contractor support and workarounds that would be difficult to employ in

a combat environment. Almost all measures of performance have improved over the past year, but most continue to be below their interim goals to achieve acceptable suitability by the time the fleet accrues 200,000 flight hours, the benchmark set by the program and defined in the Operational Requirements Document (ORD) for the aircraft to meet reliability and maintainability requirements.

- Aircraft fleet-wide availability continued to be low, averaging 51 percent over 12 months ending in October 2015, compared to a goal of 60 percent.
- Measures of reliability that have ORD requirement thresholds have improved since last year, but eight of nine measures are still below program target values for the current stage of development, although two are within 5 percent of their interim goal; one—F-35B Mean Flight Hours Between Maintenance Event (Unscheduled)—is above its target value.
- F-35 aircraft spent 21 percent more time than intended down for maintenance and waited for parts from supply for 51 percent longer than the program targeted. At any given time, from 1-in-10 to 1-in-5 aircraft were in a depot facility or depot status for major re-work or planned upgrades. Of the fleet that remained in the field, on average, only half were able to fly all missions of even a limited capability set.
- The amount of time required to repair aircraft and return them to flying status remains higher than the requirement for the system when mature, but there has been improvement over the past year.
- The program fielded new software for the Autonomic Logistics Information System (ALIS) during 2015. All fielded units transitioned from version 1.0.3 to 2.0.0 between January and April 2015. Additional increments were tested—2.0.1 and 2.0.1.1—which included software updates to correct deficiencies discovered in 2.0.1. Version 2.0.1.1 software was fielded to operational units between May and October 2015. These versions included new functions, improved interfaces, and fixes for some of the deficiencies in the earlier ALIS versions. However, many critical deficiencies remain which require maintenance personnel to implement workarounds to address the unresolved problems.

Live Fire Test and Evaluation (LFT&E)

- The F-35 LFT&E program completed one major live fire test series using an F-35C variant full-scale structural test article (CG:0001) with an installed Pratt and Whitney F135 engine. Preliminary test data analyses:
  - Demonstrated the tolerance of the F135 initial flight release (IFR) configured engine to threat-induced fuel discharge into the engine inlet
  - Confirmed the expected vulnerabilities of the fuel tank structure
- The program demonstrated performance improvements of the redesigned fuel tank ullage inerting system in the F-35B fuel system simulator (FSS). However, aircraft ground and flight tests, designed to validate the fuel system simulator tests and aircraft system integration, revealed design deficiencies that require further hardware and software modifications.
- The test plan to assess chemical and biological decontamination of pilot protective equipment is not adequate; no plans have been made to test either the Gen II or the Gen III HMDS. The Program Office is on track to evaluate the chemical and biological agent protection and decontamination systems in the full-up system-level decontamination test planned for FY16.
- The Navy completed vulnerability testing of the F-35B electrical and mission systems to the electromagnetic pulse (EMP).
- The F-35 program continues to collect data to support the lethality evaluation of the 25 mm x 137 mm PGU-48 Frangible Armor Piercing (FAP) round, a designated round for the F-35A variant, and the PGU-32/U Semi-Armor Piercing High Explosive Incendiary-Tracer (SAPHEI-T) ammunition currently designated for the F-35B and F-35C variants.

Air-Ship Integration and Ship Suitability

- The Marine Corps conducted a suitability demonstration with six operational F-35B aircraft onboard the USS *Wasp* from May 18 – 29, 2015.
  - As expected, the demonstration was not an operational test and could not demonstrate that the F-35B is operationally effective or suitable for use in combat. This is due to the following:
    - Lack of production-representative support equipment
    - Provision of extensive supply support to ensure replacement parts reached the ship faster than would be expected in deployed combat operations
    - Incompleteness of the available maintenance procedures and technical data, which required extensive use of contractor logistics support
    - Lack of flight clearance to carry and employ combat ordnance
    - Lack of the full complement of electronic mission systems necessary for combat on the embarked aircraft
    - No other aircraft, and their associated equipment, that would normally be employed with an Air Combat Element (ACE) were present, other than three MH-60S rescue helicopters
  - The USS *Wasp* demonstration event did, however, provide useful training for the Marine Corps and amphibious Navy with regards to F-35B operations onboard L-class ships, and also provided findings relevant to the eventual integration of the F-35B into the shipboard environment. However, aircraft reliability and maintainability were poor, so it was difficult for the detachment to keep more than two to three of the six embarked aircraft in a flyable status on any given day, even with significant contractor assistance. Aircraft availability during the deployment was approximately 55 percent. Around 80 percent availability

would be necessary to generate four-ship combat operations consistently with a standard six-ship F-35B detachment.
- The second phase of F-35C ship suitability testing on CVN class carriers, Developmental Test – Two (DT-2), was conducted from October 2 – 10, 2015. Ship availability delayed the start of DT-2 from the planned date in August 2015. The principal goal of DT-2 was to perform launch and recovery of the F-35C with internal stores loaded.
- The Navy continues to work on numerous air-ship integration issues including carrier Jet Blast Deflector (JBD) design limitations, as well as improving support equipment, hearing protection, and firefighting equipment.

Cybersecurity Testing
- In accordance with DOT&E and DOD policy, the JOTT developed and presented a cybersecurity operational test strategy to DOT&E for approval in February 2015. This strategy established a schedule and expectations for cybersecurity testing of the JSF air system through the end of SDD and IOT&E in late 2017. The strategy includes multiple assessments aligned with the blocks of capability as the program delivers them to the field in both the air vehicle and ALIS. The test teams will conduct the assessments on fielded, operational equipment. All testing requires coordination from the JSF Program Executive Officer, via an Interim Authority to Test (IATT). This testing is OT&E where DOT&E approves plans and independently reports results. The test strategy, approved by DOT&E, includes end-to-end testing of all ALIS components and the F-35 air vehicle.
- The JOTT began planning Cooperative Vulnerability and Penetration Assessments (CVPAs) and Adversarial Assessments (AAs) of all ALIS components in the latest configuration to be fielded—ALIS 2.0.1.1—as well as the F-35 air vehicle in the Block 2B configuration. The JOTT planned a CVPA for September 21 through October 2, 2015, and an AA from November 9 – 20, 2015. However, the test teams were not able to complete the CVPA as planned because the Program Office failed to provide an IATT due to insufficient understanding of risks posed to the operational ALIS systems by cybersecurity testing. This testing was postponed and combined with an AA, planned to take place in early November 2015. However, the Program Office approved only a partial IATT, which allowed a CVPA of the ALIS components at Edwards AFB, California, and a CVPA of the Operational Central Point of Entry (CPE)—a major network hub in the overall ALIS architecture—to proceed. Although authorized, the AA for the CPE was not accomplished because the IATT was approved too late for the AA team to make arrangements for the test. The limited testing that was permitted revealed significant deficiencies that must be corrected and highlighted the requirement to complete all planned cybersecurity testing.
- Only ALIS components were planned to be tested in these events in late 2015; inclusion of the air vehicle is planned for future events. An end-to-end enterprise event, which links each component system, including the air vehicle, is required for adequate cybersecurity operational testing.

Pilot Escape System
- The program conducted two sled tests on the pilot escape system in July and August 2015 that resulted in failures of the system to successfully eject a manikin without exceeding load/stress limits on the manikin. These sled tests were needed in order to qualify the new Gen III HMDS for flight release. In July 2015, a sled test on a 103-pound manikin with a Gen III helmet at 160 knots speed demonstrated the system failed to meet neck injury criteria. The program did not consider this failure to be solely caused by the heavier Gen III helmet, primarily due to similarly poor test results observed with the Gen II helmet on a 103-pound manikin in 2010 tests. The program conducted another sled test in August 2015 using a 136-pound manikin with the Gen III helmet at 160 knots. The system also failed to meet neck injury criteria in this test. Similar sled testing with Gen II helmets in 2010 did not result in exceedance of neck loads for 136-pound pilots.
- After the latter failure, the Program Office and Services decided to restrict pilots weighing less than 136 pounds from flying any F-35 variant, regardless of helmet type (Gen II or Gen III). Pilots weighing between 136 and 165 pounds are considered at less risk than lighter weight pilots, but still at an increased risk (compared to heavier pilots). The level of risk was labeled "serious" by the Program Office based on the probability of death being 23 percent, and the probability of neck extension (which will result in some level of injury) being 100 percent. Currently, the Program Office and the Services have decided to accept this level of risk to pilots in this weight range, although the basis for the decision to accept these risks is unknown.
- In coordination with the Program Office, the ejection seat contractor funded a proof-of-concept ejection sled test in October to assess the utility of a head support panel (HSP), a fabric mesh behind the pilot's head and between the parachute risers, to prevent exceeding neck loads during the ejection sequence for lighter weight pilots. Based on the initial results, the Program Office and Services are considering seat modifications that would include the HSP, but they may take at least a year to verify improvement and install them onto aircraft. Additional testing and analyses are also needed to determine the risk to pilots of being harmed by the transparency removal system (which shatters the canopy before, and in order for, the seat and pilot leave the aircraft) during ejections in other than ideal, stable conditions (such as after battle damage or during out-of-control situations).
- The program began delivering F-35 aircraft with a water-activated parachute release system in later deliveries of Lot 6 aircraft in 2015. This system, common in current fighter aircraft for many years, automatically jettisons the parachute when the pilot enters water after ejection; in the case of pilot incapacitation, an automatic jettisoning of the

parachute canopy is essential for aircrew survival. In June 2012, while reviewing preparations to begin training pilots at Eglin AFB, Florida, the Program Office accepted the serious risk of beginning training without the water-activated release system installed in the early production lots of training aircraft. At that time, the Program Office expected the full qualification of the system to be completed by the end of 2012.

System

- The F-35 JSF program is a tri-Service, multi-national, single-seat, single-engine family of strike aircraft consisting of three variants:
  - F-35A Conventional Take-Off and Landing (CTOL)
  - F-35B Short Take-Off/Vertical-Landing (STOVL)
  - F-35C Aircraft Carrier Variant (CV)
- It is designed to survive in an advanced threat (year 2015 and beyond) environment using numerous advanced capabilities. It is also designed to have improved lethality in this environment compared to legacy multi-role aircraft.
- Using an active electronically scanned array radar and other sensors, the F-35 is intended to employ precision-guided bombs such as the GBU-31/32 JDAM, GBU-39 SDB, Navy JSOW-C1, AIM-120C AMRAAM, and AIM-9X infrared-guided short-range air-to-air missile.
- The program provides mission capability in three increments:
  - Block 1 (initial training; two increments were fielded: Blocks 1A and 1B)
  - Block 2 (advanced training in Block 2A and limited combat capability in Block 2B)
  - Block 3 (limited combat in Block 3i and full combat capability in Block 3F)
- The F-35 is under development by a partnership of countries: the United States, Great Britain, Italy, the Netherlands, Turkey, Canada, Australia, Denmark, and Norway.

Mission

- The Combatant Commander will employ units equipped with F-35 aircraft to attack targets during day or night, in all weather conditions, and in highly defended areas of joint operations.
- The F-35 will be used to attack fixed and mobile land targets, surface units at sea, and air threats, including advanced aircraft and cruise missiles.

Major Contractor

Lockheed Martin, Aeronautics Division – Fort Worth, Texas

Test Strategy, Planning, and Resourcing

- The Program Office continues to plan for a start of IOT&E in August 2017, three months after the program's planned completion of developmental flight test in May 2017, or one month later than the recently briefed date of July 2017. In the intervening three months, the program must complete all the analyses and certification requirements to allow final preparations for IOT&E to begin. There are clear indications that it is no longer possible to meet the requirements to start an adequate IOT&E at that time. Specifically:
  - The program's joint test plans for Block 3F mission systems testing contain more testing than can be completed by May 2017, which is the planned end of Block 3F flight test, according to the most recent program schedule. Even extending until the end of July 2017 to compete System Development and Demonstration (SDD) flight test is not realistic. Instead, the program will likely not finish Block 3F development and flight testing prior to January 2018, based on the following:
    - Continuing a six test point per flight accomplishment rate, which is equal to the CY15 rate observed through the end of November
    - Continuing a flight rate of 6.8 flights per month with the 6 mission systems developmental test aircraft assigned to Edwards AFB, as was achieved through the end of November 2015, exceeding the planned rate of 6 flights per month (if the flight rate deteriorates to the planned rate of 6 flights per month, then testing will not complete until May 2018)
    - Completing the full Block 3F mission systems test plan (i.e., all original 7,230 baseline and budgeted non-baseline test points in the Block 3F joint test plan)
    - Continuing the CY15 discovery rate of 5 percent
  - Based on these projected completion dates for Block 3F developmental testing, IOT&E would not start earlier than August 2018. The program could, as has been the case in testing previous software increments, determine that test points in the plan are no longer required for the Block 3F fleet release. However, the program will need to ensure that deleting and/or deferring testing from Block 3F before the end of SDD and the start of IOT&E does not result in increasing the likelihood of discovery in IOT&E or affect the assessment of mission capability. Whatever capability the program determines as ready for IOT&E will undergo the same realistic and rigorous combat mission-focused testing as a fully functioning system.
  - The 48 Block 3F developmental test weapons delivery accuracy (WDA) events in the approved Test and Evaluation Master Plan (TEMP), plus two test events deferred from Block 2B, will not be accomplished by the planned date of May 2017, according to the program's official schedule, nor by July 2017, a more recently briefed date for the completion of SDD flight test, unless the program is able to significantly increase their historic WDA completion rate. In order to meet the schedule requirements for weapon certification, the Program Office has identified 10 WDA events for the F-35A and 5 events

for the F-35B and F-35C that must be accomplished during Block 3F developmental testing. The program plans to accomplish the remaining 33 events as schedule margin allows.
- Modifying the fleet of operational test aircraft to the required production-representative Block 3F configuration, with the TEMP-required instrumentation capability, will not be complete before August 2017.
- The Program Office did not put the Block 3F Verification Simulation (VSim) development on contract in early 2015, as was needed in order to complete development for IOT&E. The Program Office decided instead to move from VSim to the Joint Simulation Environment (JSE), which will result in a fully verified, validated, and accredited simulator not being ready in time for IOT&E.

• Comparison testing provides insight into the capabilities available from new weapon systems relative to the legacy systems they replace. Since the Department plans to retire a large portion of its tactical aircraft inventory and replace them over time with the F-35, comparison testing will be a part of the Block 3F IOT&E. The JSF Operational Test Team (JOTT), in coordination with DOT&E staff, began to develop test plans for IOT&E, which will include comparisons of the F-35 with the A-10 in the Close Air Support role and with the F-16C (Block 50) in the Suppression of Enemy Air Defense/Destruction of Enemy Air Defenses (SEAD/DEAD) mission area. Comparison testing involving other strike aircraft is under consideration by the JOTT and DOT&E.
• JSF follow-on development will integrate additional capabilities in Block 4, address deferrals from Block 3F to Block 4, and correct deficiencies discovered during Block 3F development and IOT&E.
  - The program plans to complete Block 3F software development in 2016 and flight testing in early 2017. The next planned software delivery will be a Block 4 build in 2020, creating a four year gap between planned software releases. Considering the large number of open deficiencies documented from Blocks 2B and 3i testing, the ongoing discovery of deficiencies during Block 3F testing, and the certainty of more discoveries from IOT&E, the program needs to plan for additional Block 3F software builds and follow-on testing prior to 2020.
  - As has been the case with the F-22, the F-35 program will remain on DOT&E oversight during follow-on development and therefore must plan for and fund an associated formal OT&E of each Block 4 increment prior to release to operational units.
• The program has proposed a "block buy" combining three production lots comprising as many as 270 U.S. aircraft purchases to gain near-term savings. A commitment to the "block buy" could be necessary before IOT&E is complete. In that case, entering a "block buy" would raise the following questions:
  - Is the F-35 program sufficiently mature to commit to the "block buy?" The program continues to discover significant problems during developmental testing that, if not addressed with corrections or, in some cases, labor-intensive workarounds, will adversely affect the operational effectiveness and suitability of all three variants; these deficiencies need to be corrected before the system is used in combat. To date, the rate of deficiency correction has not kept pace with the discovery rate. Examples of well-known significant problems include the immaturity of the Autonomic Logistics Information System (ALIS), Block 3F avionics instability, and several reliability and maintainability problems with the aircraft and engine. Much of the most difficult and time-consuming developmental testing, including approximately 50 complex WDA events, remains to be completed. Hence, new discoveries, some of which could further affect the design or delay the program, are likely to occur throughout the time the Department could commit to the "block buy." Recent discoveries that require design changes, modifications, and regression testing include the ejection seat for safe separation, wing fuel tank over-pressurization, and the life-limitations of the F-35B bulkhead. For these specific reasons and others, further program delays are likely.
  - Is it appropriate to commit to a "block buy" given that essentially all the aircraft procured thus far require modifications to be used in combat? Although still officially characterized as low-rate, F-35 production rates are already high. Despite the problems listed above, F-35 production rates have been allowed to steadily increase to large rates, well prior to the IOT&E and official Full-Rate Production (FRP) decision. Due to this concurrency of development and production, approximately 340 aircraft will be produced by FY17 when developmental testing is currently planned to end, and over 500 aircraft by FY19 when IOT&E will likely end and the FRP milestone decision should occur. These aircraft will require a still-to-be-determined list of modifications in order to provide full Block 3F combat capability. However, these modifications may be unaffordable for the Services as they consider the cost of upgrading these early lots of aircraft while the program continues to increase production rates in a fiscally-constrained environment. This may potentially result in left-behind aircraft with significant limitations for years to come.
  - Would committing to a "block buy" prior to the completion of IOT&E provide the contractor with needed incentives to fix the problems already discovered, as well as those certain to be discovered during IOT&E? Would it be preferred—and would it provide a strong incentive to fix problems and deliver fully combat-capable aircraft—to make the "block buy," as well as any additional increases in the already high annual production rate, contingent upon successful completion of IOT&E? Similarly, would the "block buy" also be consistent with the "fly before you buy" approach to acquisition advocated by the Administration, as well as with the rationale for the

operational testing requirements specified in Title 10 U.S. Code?

- This report includes assessments of the progress of testing to date, including developmental and operational testing intended to verify performance prior to the start of IOT&E.
  - For developmental flight testing, the program creates plans by identifying specific test points (discrete measurements of performance under specific flight test conditions) for accomplishment in order to determine capabilities as being compliant with contract specifications.
    - Baseline test points refer to points in the test plans that must be accomplished in order to evaluate if performance meets contract specifications.
    - Non-baseline test points are accomplished for various reasons. Program plans include a budget for some of these points within the capacity of flight test execution. The following describes non-baseline test points.
      - Development points are test points required to "build up" to, or prepare for, the conditions needed for specification compliance (included in non-baseline budgeted planning in CY15).
      - Regression points are test points flown to ensure that new software does not introduce discrepancies as compared to previous software (included in non-baseline budgeted planning in CY15).
      - Discovery points are test points flown to investigate root causes or characterize deficiencies so that the program can design fixes (not included in planning in CY15).
  - As the program developed plans for allocating test resources against test points in CY15, the program included a larger budget for non-baseline test points (development and regression points) for all test venues (i.e., each variant of flight sciences and mission systems). For CY15 mission systems testing, planners budgeted an additional 45 percent of the number of planned baseline test points for non-baseline test purposes (e.g., development and regression points). In this report, growth in test points refers to points flown in addition to the planned amount of baseline and budgeted non-baseline points (e.g., discovery points and any other added testing not originally included in the formal test plan). The program allocates budgeted non-baseline test points in specific quantities to test categories (i.e., variant flight science, Block 2B, 3i, and 3F mission systems).
  - The need to budget for non-baseline test points in the CY15 plan is a result of the limited maturity of capability in the early versions of mission systems software. In CY15, when the first versions of Block 3F software were planned to be introduced to flight testing, limited baseline test points could be completed and development points would be the majority of the type of points flown. Also, as three versions of Block 3F software were planned to be introduced to flight testing in CY15, the test centers would need to accomplish a large number of regression points.
  - Cumulative SDD test point data in this report refer to the total progress towards completing development at the end of SDD.

TEST FLIGHTS (AS OF NOVEMBER 2015)

	All Testing	Flight Sciences			Mission Systems
	All Variants	F-35A	F-35B	F-35C	
2015 Actual	1,193	188	283	270	452
2015 Planned	1,281	231	311	256	483
Difference from Planned	7.4%	22.9%	9.9%	-5.2%	6.9%
Cumulative Planned	6,242	1,489	1,844	1,188	1,721
Cumulative Actual	6,416	1,466	1,893	1,193	1,864
Difference from Planned	2.8%	-1.5%	2.7%	0.4%	8.3%
Prior to CY15 Planned	5,049	1,301	1,561	918	1,269
Prior to CY15 Actual	5,135	1,235	1,582	937	1,381

TEST POINTS (AS OF NOVEMBER 2015)												
	All Testing	Flight Sciences[1]						Mission Systems				
		F-35A		F-35B		F-35C						
	All Variants	Block 3F Baseline	Budgeted Non-Baseline[2]	Block 3F Baseline	Budgeted Non-Baseline[2]	Block 3F Baseline	Budgeted Non-Baseline[2]	Block 2B	Block 3i	Block 3F	Budgeted Non-Baseline[2]	Other[3]
2015 Test Points Planned (by type)	8,673	1,221	113	2,181	211	1,819	130	143	514	575	1,097	669
2015 Test Points Accomplished (by type)	8,011	1,196	62	2,003	191	1,910	59	160	469	674	834	453
Difference from Planned	-7.6%	-2.0%	-45.1%	-8.2%	-9.5%	5.0%	-54.6%	11.9%	-8.8%	17.2%	-24.0%	-32.3%
Points Added Beyond Budgeted Non-Baseline (Growth Points)	457	0		0		0		93	364	0	0	0
Test Point Growth Percentage (Growth Points/Test Points Accomplished)	5.7%	0.0%		0.0%		0.0%		58.1%	77.6%	0.0%	0.0%	0.0%
Total Points (by type) Accomplished in 2015[4]	8,468	1,258		2,194		1,969		253	833	674	834	453
Cumulative Data												
Cumulative SDD Planned Baseline[5]	43,611	10,919		13,995		10,650		6,232	699	575	N/A	541
Cumulative SDD Actual Baseline	43,528	10,978		13,835		10,729		5,933	660	674	N/A	719
Difference from Planned	-0.2%	0.5%		-1.1%		0.7%		-4.8%	-5.6%	17.2%	N/A	32.9%
Estimated Test Baseline Points Remaining	12,905	1,597		3,250		2,428		0	0	4,841	N/A	789
Estimated Non-Baseline Test Points Remaining	2,175	139		443		270		0	0	1,323	N/A	0

1. Flight sciences test points for CY15 are shown only for Block 3F. Block 2B Flight Sciences testing was completed in CY14 for F-35A, May 2015 for F-35B, and January 2015 for F-35C. Cumulative numbers include all previous flight science activity.
2. These points account for planned development and regression test points built into the 2015 plan; additional points are considered "growth".
3. Represents mission systems activity not directly associated with Block capability (e.g., radar cross section characterization testing, test points to validate simulator).
4. Total Points Accomplished = 2015 Baseline Accomplished + Added Points
5. SDD – System Design and Development

F-35A Flight Sciences

Flight Test Activity with AF-1, AF-2, and AF-4 Test Aircraft

- F-35A flight sciences testing focused on:
  - Internal gun testing
  - Flight envelope expansion with external weapons required for Block 3F weapons capability
  - Air refueling qualification with Italian and Australian tanker aircraft
  - Testing to mitigate fuel system over-pressurization conditions caused by fuel and On-Board Inert Gas Generation System (OBIGGS) gas pressure stacking within the system

F-35A Flight Sciences Assessment

- Through the end of November, the test team flew 23 percent more flights than planned (231 flown versus 188 planned), but was 2 percent behind the plan for Block 3F baseline test point completion (1,196 test points accomplished versus 1,221 planned). By the end of November 2015, the test team flew an additional 62 test points for regression of new air vehicle software (which were part of the budgeted non-baseline test points allocated for the year) and 238 points for air refueling qualification with partner nation tanker aircraft (these points are not included in the table of test flights and test points above). All F-35A flight sciences

testing accomplished in CY15 was relevant to Block 3F requirements.

- All Block 2B flight sciences test points were completed in CY14 and provided the basis for the F-35A Block 2B fleet release to the training and operational units in August 2015. The Block 2B flight sciences test points also provided the basis for Block 3i initial flight clearances needed for Lot 6 and Lot 7 production aircraft delivered in CY15. There is no additional flight envelope provided by Block 3i compared to Block 2B.
- The following details discoveries in F-35A flight sciences testing:
  - Testing to characterize the thermal environment of the weapons bays demonstrated that temperatures become excessive during ground operations in high ambient temperature conditions and in-flight under conditions of high speed and at altitudes below 25,000 feet. As a result, during ground operations, fleet pilots are restricted from keeping the weapons bay doors closed for more than 10 cumulative minutes prior to take-off when internal stores are loaded and the outside air temperature is above 90 degrees Fahrenheit. In flight, the 10-minute restriction also applies when flying at airspeeds equal to or greater than 500 knots at altitudes below 5,000 feet; 550 knots at altitudes between 5,000 and 15,000 feet; and 600 knots at altitudes between 15,000 and 25,000 feet. Above 25,000 feet, there are no restrictions associated with the weapons bay doors being closed, regardless of temperature. The time limits can be reset by flying 10 minutes outside of the restricted conditions (i.e., slower or at higher altitudes). This will require pilots to develop tactics to work around the restricted envelope; however, threat and/or weather conditions may make completing the mission difficult or impossible using the work around.
  - Testing to characterize the vibrational and acoustic environment of the weapons bays demonstrated that stresses induced by the environment were out of the flight qualification parameters for both the AIM-120 missile and the flight termination system (telemetry unit attached to the missile body required to satisfy range safety requirements for terminating a live missile in a flight test). This resulted in reduced service life of the missile and potential failure of the telemetered missile termination system required for range safety.
  - Deficiencies in the sequencing of release commands for the Small Diameter Bomb (SDB) from the Bomb Rack Unit-61, which provides the interface between the SDB and the aircraft, were discovered in the lab and verified in aircraft ground testing. The program will assess software corrections to address these deficiencies in future flight testing.
  - Mechanical rubbing between the gun motor drive and the wall of the gun bay was discovered during initial ground testing of the gun on the AF-2 test aircraft, requiring structural modifications to the bay and alterations to the flow of cooling air and venting of gun gasses.
  - Under certain flight conditions, air enters the siphon fuel transfer line and causes the pressure in the siphon fuel tank to exceed allowable limits in all variants. As a result, the program imposed an aircraft operating limitation (AOL) on developmental test aircraft limiting maneuvering flight for each variant (e.g. "g" load during maneuvering). F-35A developmental test aircraft with the most recent fuel tank ullage inerting system modifications are limited to 3.8 g's when the aircraft is fully fueled. The allowable g increases as fuel is consumed and reaches the full Block 2B 7.0 g envelope (a partial envelope compared to full Block 3F) once total fuel remaining is 10,213 pounds or less, or roughly 55 percent of full fuel capacity, for developmental test aircraft with test control team monitoring (through instrumentation) of the fuel system. For developmental test aircraft without fuel system monitoring, the full Block 2B 7.0 g envelope becomes available at 9,243 pounds, or roughly 50 percent of full fuel capacity. Flight testing to clear the F-35A to the full Block 3F 9.0 g envelope, planned to be released in late 2017, is being conducted with developmental test aircraft with fuel system monitoring. Fleet F-35A aircraft are limited to 3.0 g's when fully fueled and the allowable g is increased as fuel is consumed, reaching the full Block 2B 7.0 g envelope when approximately 55 percent of full fuel capacity is reached. The program modified the AF-4 test aircraft in October and November with the addition of a relief line, controlled by a solenoid valve, to vent the affected siphon tanks, and a check valve on the inert gas line feeding the tanks. The test team completed testing of the modified design in late November 2015; the results are under review. Until relieved of the g restrictions, operational units will have to adhere to a reduced maneuvering (i.e., less "g available") envelope in operational planning and tactics; for example, managing threat engagements and escape maneuvers when in the restricted envelope where less g is available. This restriction creates an operational challenge when forward operating locations or air refueling locations are close to the threat/target arena, resulting in high fuel weights during engagements.
  - Testing of operational "dog-fighting" maneuvers showed that the F-35A lacked sufficient energy maneuverability to sustain an energy advantage over fourth generation fighter aircraft. Test pilots flew 17 engagements between an F-35A and an F-16D, which was configured with external fuel tanks that limited the F-16D envelope to 7.0 g's. The F-35A remained at a distinct energy disadvantage on every engagement. Pitch rates were also problematic, where full aft stick maneuvers would result in less than full permissible g loading (i.e., reaching 6.5 g when limit was 9.0 g), and subsequent rapid loss of energy. The slow pitch rates were observed at slower speeds—in a gun engagement, for example—that restricted the ability of an F-35A pilot to track a target for an engagement.

- The program completed the final weight assessment of the F-35A air vehicle for contract specification compliance in April with the weighing of AF-72, a Lot 7 production aircraft. Actual empty aircraft weight was 28,999 pounds, 372 pounds below the planned not-to-exceed weight of 29,371 pounds. The program has managed the weight growth of the F-35A air vehicle with no net weight growth for the 76 months preceding the final weight assessment. Weight management of the F-35A is important for meeting performance requirements and structural life expectations. The program will need to continue disciplined management of the actual aircraft weight beyond the contract specification as further discoveries during the remainder of SDD may add weight and result in performance degradation that would adversely affect operational capability.

F-35B Flight Sciences

Flight Test Activity with BF-1, BF-2, BF-3, BF-4, and BF-5 Test Aircraft

- F-35B flight sciences focused on:
  - Completing Block 2B flight envelope testing by the end of May
  - Flight envelope expansion with external weapons, including Paveway IV bombs, required for Block 3F weapons capability
  - Testing to characterize and mitigate fuel system over-pressurization conditions caused by fuel and OBIGGS gas pressure stacking within the system
  - Air refueling testing, including low altitude air refueling with KC-130 tanker aircraft
  - Testing of control authority during landings in crosswind conditions, both with and without external stores

F-35B Flight Sciences Assessment

- Through the end of November, the test team was able to fly 10 percent more flights than planned (311 flown versus 283 planned), but accomplished 8 percent less than the planned Block 3F baseline test points (2,003 points accomplished versus 2,181 planned). The team flew an additional 191 test points for regression of new air vehicle software, which were part of the budgeted non-baseline points planned for CY15. The team also completed four test points needed to complete the Block 2B flight envelope. The program also declared that 23 planned Block 2B baseline points were no longer required.
- The following details discoveries in F-35B flight sciences testing:
  - Testing to characterize the thermal environment of the weapons bays demonstrated that temperatures become excessive during ground operations in high ambient temperature conditions. As a result, during ground operations, fleet pilots are restricted from keeping the weapons bay doors closed for more than 10 cumulative minutes prior to take-off when internal stores are loaded and the outside air temperature is above 90 degrees Fahrenheit. Time with the weapons bay doors closed in flight is currently not restricted.
  - Under certain flight conditions, air can enter the siphon fuel transfer line and cause the pressure in the siphon fuel tanks to exceed allowable limits in all variants. As a result, the program imposed an aircraft operating limitation (AOL) on developmental test aircraft limiting maneuvering flight for each variant. The program implemented a partial mitigation in software on the F-35B. For F-35B developmental aircraft with the most recent fuel tank ullage inerting system modifications, the AOL limits maneuvers to 5.0 g's when the aircraft is fully fueled, but the allowable g increases as fuel is consumed. The full Block 2B 5.5 g envelope (a partial envelope compared to Block 3F) is available once total fuel remaining is approximately 13,502 pounds, or roughly 96 percent fuel remaining for developmental test aircraft with ground station monitoring of the fuel system, and 7,782 pounds or less, or roughly 56 percent fuel remaining for developmental test aircraft without monitoring. Flight testing to clear the F-35B to the full Block 3F 7.0 g envelope, planned to be released in late 2017, is being conducted with developmental test aircraft with fuel system monitoring. Fleet F-35B aircraft are limited to 3.0 g's when fully fueled and the allowable g is increased as fuel is consumed, reaching the full Block 2B envelope of 5.5 g's at roughly 63 percent of fuel remaining. The program has successfully developed and tested a hardware change on the F-35B to correct the overpressure problem involving the addition of a relief line controlled by a check valve to vent the affected siphon tanks. Once installed in fleet aircraft, the relief line and check valve will prevent the pressure in the siphon tanks from exceeding the allowable limits. Until the F-35B aircraft have the modification that relieves the g restrictions, operational units will have to adhere to a reduced maneuvering (i.e., less "g available") envelope in operational planning and tactics; for example, managing threat engagements and escape maneuvers when in the restricted envelope where less g is available. This restriction creates an operational challenge when forward operating locations or air refueling locations are close to the threat/target arena.
  - Air refueling with strategic tankers (KC-135 and KC-10) was restricted to use of centerline boom-to-drogue adapter (BDA) refueling only. Refueling from tanker wing pods was prohibited due to response anomalies from the hose and reel assemblies and the F-35B aircraft with the air refueling receptacle deployed.
- Weight management of the F-35B aircraft is critical to meeting the Key Performance Parameters (KPPs) in the Operational Requirements Document (ORD), including the vertical lift bring-back requirement, which will be evaluated during IOT&E. This Key Performance Parameter (KPP) requires the F-35B to be able to fly an operationally representative profile and recover to the ship with the necessary fuel and balance of unexpended weapons (two 1,000-pound bombs and two AIM-120 missiles) to safely conduct a vertical landing.

- The program completed the final weight assessment of the F-35B air vehicle for contract specification compliance in May 2015 with the weighing of BF-44, a Lot 7 production aircraft. Actual empty aircraft weight was 32,442 pounds, only 135 pounds below the planned not-to-exceed weight of 32,577 pounds and 307 pounds (less than 1 percent) below the objective vertical lift bring-back not-to-exceed weight of 32,749 pounds.
- The program will need to continue disciplined management of weight growth for the F-35B, especially in light of the small weight margin available and the likelihood of continued discovery through the remaining two years of development in SDD.

F-35C Flight Sciences

Flight Test Activity with CF-1, CF-2, CF-3, and CF-5 Test Aircraft

- F-35C flight sciences focused on:
  - Completing Block 2B testing by the end of January 2015
  - Ship suitability testing in preparation for the next set of ship trials (DT-2), originally planned for August, but slipped to October 2015 due to carrier availability
  - Flight envelope expansion with external weapons, required for Block 3F weapons capability
  - Testing with wing spoilers to reduce the adverse effects of transonic roll off in the portions of the flight envelope where it occurs
  - High angle of attack testing
  - Testing of control authority during landings in crosswind conditions, both with and without external stores
  - Testing of landings on wet runways and the effectiveness of anti-skid braking procedures
  - Air refueling testing
  - Initial testing of the Joint Precision Approach and Landing System

F-35C Flight Sciences Assessment

- Through the end of November, the test team flew 5 percent less than planned flights (256 flown versus 270 planned), but accomplished 5 percent more than the planned Block 3F baseline test points (1,910 points accomplished versus 1,819 planned). The team flew an additional 59 test points for regression of new software, which were part of the budgeted non-baseline points planned for the year. With the exception of three high angle of attack test points in January for the Block 2B envelope, all testing in CY15 supported Block 3F testing requirements.
- The following details discoveries in F-35C flight sciences testing:
  - Under certain flight conditions, air can enter the siphon fuel transfer line and cause the pressure in the siphon fuel tank to exceed allowable limits in all variants. The program imposed an AOL on developmental test aircraft, limiting maneuvering flight for each variant. On F-35C developmental test aircraft with the most recent fuel tank ullage inerting system modifications, the AOL limits maneuvers to 4.0 g's when the aircraft is fully fueled and the allowable g increases as fuel is consumed. The full Block 2B 6.0 g envelope (a partial envelope compared to Block 3F) is available with 18,516 pounds or roughly 93 percent fuel remaining for developmental test aircraft with test control team monitoring (through instrumentation) of the fuel system, and 8,810 pounds or roughly 40 percent fuel remaining for developmental test aircraft without monitoring. Flight testing to clear the F-35C to the full Block 3F 7.5 g envelope, planned to be released in late 2017, is being conducted with developmental test aircraft with fuel system monitoring. The program has developed and tested a correction involving the addition of a relief line controlled by a check valve to vent the affected siphon tanks on the F-35B, which has very similar fuel system siphoning architecture as the F-35C. However, the program has not tested the pressure relief design in flight on an F-35C. Fleet F-35C aircraft are limited to 3.0 g's when fully fueled and the allowable g is increased as fuel is consumed, reaching the full Block 2B envelope of 6.0 g's at roughly 43 percent of total fuel quantity remaining. Until relieved of the g restrictions, operational units will have to adhere to a reduced maneuvering (i.e., less "g available") envelope in operational planning and tactics; for example, managing threat engagements and escape maneuvers when in the restricted envelope where less g is available. This restriction creates an operational challenge when forward operating locations or air refueling locations are close to the threat/target arena.
  - Air refueling with strategic tankers (KC-135 and KC-10) was restricted to use of centerline BDA refueling only. Refueling from tanker wing pods was prohibited due to response anomalies from the hose and reel assemblies and the F-35C aircraft with the air refueling receptacle deployed.
  - The Patuxent River test center (Maryland) conducted an assessment of the effects of transonic roll off (TRO), which is an un-commanded roll at transonic Mach numbers and elevated angles of attack. The test center also assessed buffet, which is the impact of airflow separating from the leading edge of the wing that collides and "buffets" aft areas of the wing and aircraft on basic fighter maneuvering. TRO and buffet occur in areas of the maneuvering envelope that cannot be sustained for long periods of time, as energy depletes quickly and airspeed transitions out of the flight region where these conditions manifest. However fleeting, these areas of the envelope are used for critical maneuvers. The testing determined that TRO, observed to cause up to 8 degrees angle of bank, adversely affected performance in defensive maneuvering where precise control of bank angles and altitude must be maintained while the F-35C is in a defensive position and the pilot is monitoring an offensive aircraft. The test pilots observed less of an effect when the F-35C is conducting offensive maneuvering. However, buffet degrades precise

aircraft control and the readability of heads-up-display symbology in the HMDS during execution of certain critical offensive and defensive tasks, such as defensive maneuvers.
  - The program completed two test flights in February with CF-2, an instrumented flight sciences test aircraft modified with spoilers, to investigate the effects on flying qualities when using control laws to deploy spoilers in the flight regions where buffet and TRO manifest (between Mach 0.92 and 1.02 and above 6 degrees angle-of-attack).
    - Testing showed the spoilers reduced buffet at some flight conditions, but also may increase buffet under other flight conditions, and reduced the magnitude of TRO when experienced; an observation predicted by wind tunnel testing.
    - Pilots reported that spoilers made a measurable difference in the buffet-laden region of the flight envelope but, due to the transient nature of buffet, the operational significance may be low.
    - Operational testing of the F-35C will need to assess the effect of TRO and buffet on overall mission effectiveness.
- Weight management is important for meeting air vehicle performance requirements, including the KPP for recovery approach speed to the aircraft carrier, and structural life expectations. These estimates are based on measured weights of components and subassemblies, calculated weights from approved design drawings released for build, and estimated weights of remaining components. These estimates are used to project the weight of the first Lot 8 F-35C aircraft (CF-28) planned for delivery in March 2016, which will be the basis for evaluating contract specification compliance for aircraft weight.
  - The current F-35C estimate of 34,582 pounds is 286 pounds (less than 1 percent) below the planned not-to-exceed weight of 34,868 pounds.
  - The program will need to ensure the actual aircraft weight meets predictions and continue rigorous management of the actual aircraft weight beyond the technical performance measurements of contract specifications in CY16. The program will need to accomplish this through the balance of SDD to avoid performance degradation that would affect operational capability.

Mission Systems

Flight Test Activity with AF-3, AF-6, AF-7, BF-4, BF-5, BF-17, BF-18, CF-3, and CF-8 Flight Test Aircraft and Software Development Progress

- Mission systems are developed, tested, and fielded in incremental blocks of capability.
  - Block 1. The program designated Block 1 for initial training capability in two increments: Block 1A for Lot 2 (12 aircraft) and Block 1B for Lot 3 aircraft (17 aircraft). No combat capability is available in either Block 1 increment. The Services have upgraded a portion of these aircraft to the Block 2B configuration through a series of modifications and retrofits. As of the end of November, 9 F-35A and 12 F-35B aircraft had been modified to the Block 2B configuration and 4 F-35A were undergoing modifications. Two F-35B aircraft, which are on loan to the Edwards AFB test center to support mission systems developmental flight testing, have been modified to the Block 3F configuration, leaving one F-35A and one F-35B in the Block 1B configuration. Additional modifications will be required to configure these aircraft in the Block 3F configuration.
  - Block 2A. The program designated Block 2A for advanced training capability and delivered aircraft in production Lots 4 and 5 in this configuration. No combat capability is available in Block 2A. The U.S. Services accepted 62 aircraft in the Block 2A configuration (32 F-35A aircraft in the Air Force, 19 F-35B aircraft in the Marine Corps, and 11 F-35C aircraft in the Navy). Similar to the Block 1A and Block 1B aircraft, the Services have upgraded these aircraft to the Block 2B configuration with modifications and retrofits, although fewer modifications were required. By the end of September, all 62 Lot 4 and 5 aircraft had been modified to the Block 2B configuration. One F-35C aircraft, which is on loan to the Edwards AFB test center, has been modified to the Block 3F configuration to support mission systems developmental flight testing. Additional modifications will be required to fully configure these aircraft in the Block 3F configuration.
  - Block 2B. The program designated Block 2B for initial, limited combat capability for selected internal weapons (AIM-120C, GBU-31/32 JDAM, and GBU-12). This block is not associated with the delivery of any lot of production aircraft. Block 2B mission systems software began flight testing in February 2013 and finished in April 2015. Block 2B is the software that the Marine Corps accepted for the F-35B Initial Operational Capability (IOC) configuration.
  - Block 3i. The program designated Block 3i for delivery of aircraft in production Lots 6 through 8, as these aircraft include a set of upgraded integrated core processors (referred to as Technical Refresh 2, or TR-2). The program delivered Lot 6 aircraft with a Block 3i version that included capabilities equivalent to Block 2A in Lot 5. Lot 7 aircraft are being delivered with capabilities equivalent to Block 2B, as will Lot 8 aircraft. Block 3i software began flight testing in May 2014 and completed baseline testing in October 2015, eight months later than planned in the Integrated Master Schedule (IMS). The program completed delivery of the U.S. Service's Lot 6 aircraft in 2015 (18 F-35A, 6 F-35B, and 7 F-35C aircraft). The delivery of Lot 7 aircraft began in August 2015, with four F-35A aircraft delivered to the U.S. Air Force. By the end of November, the program had delivered 13 F-35A

Lot 7 aircraft to the U.S. Air Force and two F-35B Lot 7 aircraft to the Marine Corps.
  - Block 3F. The program designated Block 3F as the full SDD capability for production Lot 9 and later. Flight testing with Block 3F software on the F-35 test aircraft began in March 2015. Aircraft from production Lots 2 through 5 will need to be modified, including the installation of TR-2 processors, to have Block 3F capabilities.
- Mission systems testing focused on:
  - Completing Block 2B flight testing
  - Completing Block 3i flight testing
  - Beginning Block 3F flight testing
  - Regression testing of corrections to deficiencies identified in Block 2B and Block 3i flight testing
  - Testing of the Gen III HMDS
- The six mission systems developmental flight test aircraft assigned to the Edwards AFB test center flew an average rate of 6.8 flights per aircraft, per month in CY15 through November, exceeding the planned rate of 6.0 by 13 percent, and flew 107 percent of the planned flights (483 flights accomplished versus 452 planned).
- The program prioritized flight test activity early in the year to complete Block 2B flight testing. The program declared testing complete on Block 2B software at the end of April. The program made the decision, in part, based on schedule, to support the need for moving forward with Block 3i and Block 3F testing, which required modifying the mission systems test aircraft with upgraded TR-2 processors.
- The Edwards AFB test center used production operational test aircraft, assigned to the operational test squadron there, to assist in accomplishing developmental test points of Block 2B capabilities throughout the year, including augmenting testing requiring formation flight operations.

Mission Systems Assessment

- Block 2B Development
  - The program completed Block 2B mission systems testing and provided a fleet release version of the software with deficiencies identified during testing.
  - The program attempted to correct deficiencies in the fusion of information—from the sensors on a single aircraft and between aircraft in formation—identified during flight testing in late CY14 and early CY15 of the planned final Block 2B software version. The test team flew an "engineering test build" (ETB) of the software designated 2BS5.2ETB. on 17 test flights using 3 different mission systems test aircraft in March. Although some improvement in performance was observed, distinguishing ground targets from clutter continued to be problematic. As a result, the program chose to field the final (prior to the ETB) version of Block 2B software and defer corrections to Block 3i and Block 3F.
  - Five mission systems deficiencies were identified by the Air Force as "must fix" for the final Block 3i software release, while the Marine Corps did not require the deficiencies to be fixed in Block 2B. These deficiencies were associated with information displayed to the pilot in the cockpit concerning performance and accuracy of mission systems functions related to weapon targeting, radar tracking, status of fused battlespace awareness data, health of the integrated core processors, and health of the radar. Another deficiency was associated with the time it takes to download files in order to conduct a mission assessment and debriefing.
  - Continuing to work the Block 2B deficiencies would have delayed the necessary conversion of the labs and the developmental test aircraft to the Block 3i and Block 3F configuration, delaying the ability for the program to complete Block 3i testing needed for delivery of aircraft from production Lots 6 and 7, and starting flight testing of Block 3F software.
  - The program deferred two WDA events from Block 2B to Block 3F as a result of the decision to stop Block 2B testing in April. This deferred work will add more pressure to the already demanding schedule of Block 3F WDA events.
  - The program attempted to correct known deficiencies from flight testing of Block 2B software in the Block 3i software product line (i.e., mission systems labs and Block 3i flight test aircraft). The program corrected some of these deficiencies and, as of the end of November 2015, planned to transfer these corrections to a new version of Block 2B software (2BS5.3) for a release in CY16. In order to accomplish this, the program needs to use aircraft from the operational test fleet, which will still be in the Block 2B configuration, to test the 2BS5.3 software. However, this entire process introduces inefficiencies in the program's progress for developing and testing Block 3F software.
- Block 2B Fleet Release
  - The program finished Block 2B developmental testing in May (mission systems testing completed in April, and F-35B flight sciences testing completed in May) and provided the necessary data for the Service airworthiness authorities to release Block 2B capabilities to their respective fleets. The Marine Corps released Block 2B to the F-35B fielded units in June, the Air Force to the F-35A units in August, and the Navy to the F-35C units in October. The fleet release enabled the Services to load Block 2B software on their aircraft, provided they had been modified at least in part to the Block 2B configuration.
  - Because of the limited combat capability provided in Block 2B, if the Block 2B F-35 aircraft will be used in combat, it will need the support of a command and control system that will assist in target acquisition and to control weapons employment for the limited weapons carriage available. If in an opposed combat scenario, the F-35 Block 2B aircraft would need to avoid threat engagement and would require augmentation by other friendly forces. The Block 2B fleet release carries maneuver and envelope restrictions that, although agreed to by the Services during requirements reviews, will also limit effectiveness:

- For the F-35A, the airspeed at which the weapons bay doors can be open in flight (550 knots or 1.2 Mach) is less than the maximum aircraft speed allowable (700 knots or 1.6 Mach). Such a restriction will limit tactics to employment of weapons at lower speeds and may create advantages for threat aircraft being pursued by the F-35A.
- For the F-35A, the airspeed at which countermeasures can be used is also less than the maximum speed allowable, again restricting tactical options in scenarios where F-35A pilots are conducting defensive maneuvers
- The program formally vets deficiency reports submitted by test and operational organizations. The formal process assigns deficiency reports to categories correlating to urgency for correction. Category I deficiencies are those which may cause death, severe injury, or severe occupational illness; may cause loss or major damage to a weapon system; critically restrict the combat readiness capabilities of the using organization; or result in a production line stoppage. Category II deficiencies are those that impede or constrain successful mission accomplishment (but do not meet the safety or mission impact criteria of a Category I deficiency). As of the end of October 2015, 91 Category 1 (mission or safety of flight impact, 27) and Category 2 (mission impact, 64) high-severity deficiencies in the full Block 2B configuration (air vehicle, propulsion, mission systems) were not yet resolved by the program. Of these 91, 43 are assigned to mission systems engineering for resolution.
- In addition to the mission systems deficiencies cited above, the Block 2B fleet aircraft are restricted by fuel system deficiencies:
  - All variants of the fleet Block 2B aircraft are restricted from exceeding 3 gs in symmetric maneuvers when fully fueled in order to avoid exceeding the allowable pressure in the siphon fuel tanks. The allowable g increases as fuel is consumed. The program has developed and tested a hardware correction to the problem for the F-35B; corrections for the F-35A and F-35C are still in work. Modification kits for installation on fielded production aircraft are currently in production for the F-35B and aircraft delivered in production Lot 8 will include the correct hardware. This modification will restore the envelope of the F-35B.
  - The program lifted the restriction preventing the F-35B from flying within 25 nautical miles of known lightning prior to the declaration of IOC; however, the program has added a restriction from taxiing or taking off within 25 nautical miles of known lightning because of only a partial software mitigation to the siphon tank overpressure problem. The program plans to field a new software release in 1QCY16, which will enable a hardware correction to the overpressure problem, once fielded F-35B aircraft are retrofitted with the hardware modification.

- Block 3i
  - Block 3i flight testing began in May 2014 with version 3iR1, derived from Block 2A software, six months later than planned in the IMS. The latest version of Block 3i software—3iR6—began flight testing in July 2015 and was derived from the latest version of Block 2B software. Block 3i mission systems flight testing completed in October 2015, eight months later than planned in the IMS.
  - Since the program planned to not introduce new capabilities in Block 3i, the test plan was written to confirm Block 3i had equivalent capabilities to those demonstrated in Block 2A (for 3iR1) and Block 2B (for subsequent versions of Block 3i software). The program's plan required completion of 514 baseline test points by mid-February 2015, with additional development, regression, and discovery points flown as necessary for each increment of software to address deficiencies. The program completed Block 3i mission systems testing by accomplishing 469 of the 514 baseline Block 3i test points, or 91 percent. Of the 45 test points remaining, 6 were transferred for completion in Block 3F and the remaining 39 were designated as "no longer required." The program executed an additional 515 test points. Of those 515 points, 151 were allocated in the budgeted non-baseline points for the year, and the 364 additional points represent growth in Block 3i testing. These 364 additional points, needed to accomplish the 469 baseline test points, represent a growth of 78 percent, which is much higher than the non-baseline budgeted of 30 percent planned by the program to complete Block 3i testing.
  - Results from 3iR6 flight testing demonstrated partial fixes to the five "must fix for Air Force IOC" deficiencies, showing some improved performance. Poor stability in the radar, however, required multiple ground and flight restarts, a condition that will reduce operational effectiveness in combat.
  - Instabilities discovered in the Block 3i configuration slowed progress in testing and forced development of additional software versions to improve performance. Two additional versions of the 3iR5 software were created in an attempt to address stability in start-up of the mission systems and inflight stability of the radar. Overall, radar performance has been less stable in the Block 3i configuration than in Block 2B. The test centers developed a separate "radar stability" series of tests—including both ground startup and inflight testing—to characterize the stability problems. Radar stability is measured in terms of the number of times per flight hour that either of these events occurred: a failure event requiring action by the pilot to reset the system; or, a stability event where the system developed a fault, which affected performance, but self-corrected without pilot intervention. For the last version of Block 2B software—2BS5.2—the test team measured a mean time between stability or failure event of 32.5 hours over nearly 200 hours of flight testing. For

3iR6, the time interval between events was 4.3 hours over 215 hours of flight testing. This poor radar stability will degrade operational mission effectiveness in nearly all mission areas.
  - Since no capabilities were added to Block 3i, only limited corrections to deficiencies, the combat capability of the initial operational Block 3i units will not be noticeably different than the Block 2B units. If the Block 3i F-35 aircraft will be used in combat, they will need equivalent support as for the Block 2B F-35 aircraft, as identified previously in this report.
  - As of the end of October, a total of nine Category 1 (three mission or safety of flight impact) and Category 2 (six mission impact) high-severity deficiencies in the full Block 3i configuration (air vehicle, propulsion, mission systems) were unresolved. Eight of these nine are assigned to mission systems engineering for resolution.
  - Based on these Block 3i performance issues, the Air Force briefed that Block 3i mission capability is at risk of not meeting IOC criteria to the Joint Requirements Oversight Council (JROC) in December 2015. The Air Force recently received its first Block 3i operational aircraft and is assessing the extent to which Block 3i will meet Air Force IOC requirements; this assessment will continue into mid-2016.
- Block 3F
  - Block 3F flight testing began in March 2015, six months later than the date planned by the program after restructuring in 2012.
  - As of the end of November, a total of 674 Block 3F baseline test points had been completed, compared to 575 planned (17 percent more than planned). An additional 653 development and regression points were flown, all of which were part of the budgeted non-baseline points for the year.
  - Since many of the baseline test points—which are used to confirm capability—cannot be tested until later versions of the Block 3F software are delivered in CY16 and CY17, the program allocated a large number of test points (979 for CY15) for development and regression of the software, while expecting to accomplish only 677 baseline test points in CY15. The total planned amount of baseline test points to complete Block 3F are approximately 5,467; combined with the planned non-baseline test points in the approved test plan, there are approximately 7,230 test points for Block 3F.
  - Due to the later-than-planned start of Block 3F mission systems testing (6 months late), the large amount of planned baseline test points remaining (88 percent), and the likelihood of the need for additional test points to address discoveries and fixes for deficiencies, the program will not be able to complete Block 3F missions systems flight test by the end of October 2016, as indicated by the IMS. Instead, the program will likely not finish Block 3F development and flight testing prior to January 2018, based on the following:
    - Continuing a six test point per flight accomplishment rate, which is equal to the CY15 rate observed through the end of November
    - Continuing a flight rate of 6.8 flights per month, as was achieved through the end of November 2015, exceeding the planned rate of 6 flights per month (if the flight rate deteriorates to the planned rate of 6 flights per month, then testing will not complete until May 2018).
    - Completing the full Block 3F test plan (i.e., all original 7,230 baseline and budgeted non-baseline test points in the Block 3F joint test plan)
    - Continuing the CY15 discovery rate of 5 percent
  - The program currently tracks 337 total Category 1 (42 mission or safety of flight impact) and Category 2 (295 mission impact) high-severity deficiencies in the full Block 3F configuration (air vehicle, propulsion, mission systems), of which 200 are assigned to the mission systems engineering area for resolution. An additional 100 Category 1 and Category 2 high-severity deficiencies are unresolved from Block 2B and Block 3i configurations, of which 51 are assigned to mission systems for resolution. It remains to be determined how many of these the program will be able to correct in later Block 3F versions. If any of these deficiencies are not resolved in the planned Block 3F design, additional efforts to isolate causes, and design and verify fixes will increase the amount of time needed to complete Block 3F development and testing.
  - The program could, as has been the case in testing previous software increments, determine test points in the plan are no longer required for the Block 3F fleet release. However, the program will need to ensure that deleting and/or deferring testing from Block 3F before the end of SDD and start of IOT&E does not increase the likelihood of discovery in IOT&E or affect the evaluation of mission capability. Whatever capability the program determines as ready for IOT&E will need to undergo the same rigorous and realistic combat mission-focused testing as a fully functioning system.
  - Block 3F mission systems capabilities require more complex test scenarios than prior versions of mission systems. It requires testing involving significantly more complex threat behavior and threat densities on the test ranges than was used in prior versions of mission systems. Additionally, Block 3F capability requires more testing in multi-ship formations.

Helmet Mounted Display System (HMDS)

- The HMDS is pilot flight equipment. It has a display on the visor that provides the primary visual interface between the pilot and the air vehicle and mission systems. The HMDS was envisioned to replace a traditional cockpit-mounted "heads-up display" and night vision goggles. It projects imagery from sensors onto the helmet visor, which is intended to enhance pilot situational awareness and reduce

workload. In 2010, the Program Office identified significant deficiencies and technical risk in the HMDS.

- The program created a "dual-path" approach to recover required capability.
  - One path was to fix the existing Generation II (Gen II) HMDS through redesign of the night vision system/camera and electro-optical/infrared sensor imagery integration on the visor.
  - The second path was to switch to an alternate helmet design incorporating legacy night vision goggles and projecting sensor imagery only on cockpit displays.
  - The program terminated the dual path approach in 2013 and decided to move forward with fixes to the existing Gen II HMDS which created the Gen III HMDS
- The Gen II HMDS was fielded with Block 2 and earlier configurations of aircraft. The program developed and tested improvements to address deficiencies in stability of the display (referred to as "jitter"), latency in the projection of Distributed Aperture System (DAS) imagery, and light leakage onto the display under low-light conditions (referred to as "green glow"). However, adequate improvements to the night vision camera acuity were not completed and pilots were prohibited from using the night vision camera. Pilot use of the DAS imagery was also restricted.
- The Gen III HMDS is intended to resolve all of the above deficiencies. It is a requirement for Air Force IOC in 2016, and will be used to complete SDD and IOT&E in 2018. The following provide Gen III HMDS details:
  - It includes a new higher-resolution night vision camera, software improvements, faster processing, and changes to the imagery projection systems for the visor.
  - It requires aircraft with Block 3i hardware and software.
  - Developmental flight testing began in December 2014 and will continue into 2016 with primary flight reference testing.
  - Operational testing will occur in tests conducted to support the Air Force IOC in 2016 (Block 3i), and in IOT&E (Block 3F).
  - It will be used with all Lot 7 aircraft, which are being delivered now, and later deliveries.
  - Later-than-planned escape system qualification delayed Gen III HMDS deliveries to the field; the program plans full flight clearance to occur in 2016.
- Results of the Gen III HMDS performance during developmental testing thus far indicate the following:
  - Symbology jitter and alignment. Some corrections were made for jitter and alignment in the latest configuration of the fielded Gen II HMDS via modifications to the display management computer. These are carried into the Gen III design. Developmental test pilots report less jitter and proper alignment. However, jitter still occurs in regimes of high buffet (i.e., during high g or high angle of attack maneuvering). Operational testing in heavy maneuvering environments is needed to determine if further attention will be required.
  - Green glow (difficulty setting symbology intensity level without creating a bright green glow around perimeter of display). The Gen III HMDS includes new displays with higher contrast control, which has reduced green glow compared to Gen II; the phenomena still exists, but at a manageable level, according to developmental test pilots. Developmental test pilots were able to air refuel and operate in "no moon" low illumination conditions at night. Simulated carrier approaches were also conducted at San Clemente Island off the coast of California and during carrier trials in October 2015. Operational testing in high mission task loads is also needed to confirm if further adjustments are needed.
  - Latency (projected imagery lagging head movement/placement). The Gen III HMDS includes faster processing to reduce latency in night vision camera imagery and DAS imagery projected onto the visor. The update rate in the Gen III HMDS is twice that of the Gen II. Developmental test pilots reported improvement in this area. Nonetheless, pilots have to "learn" an acceptable head-movement rate; that is, they cannot move their heads too rapidly. However, operational testing in these environments is needed to determine if the problem is resolved and pilot workload is reduced, especially during weapons employment.
  - Night vision camera resolution. The Gen II camera included a single 1280 x 1024 pixel night vision sensor. The Gen III camera includes two 1600 x 1200 sensors and additional image processing software changes, which are intended to provide improved resolution and sensitivity. Developmental test pilots reported better acuity allowing pilots to accomplish mission tasks. Operational testing under high mission task loads will determine if further improvement is needed.

Mission Data Load Development and Testing

- F-35 effectiveness in combat relies on mission data loads— which are a compilation of the mission data files needed for operation of the sensors and other mission systems—working in conjunction with the system software data load to drive sensor search parameters so that the F-35 can identify and correlate sensor detections, such as threat and friendly radar signals. The contractor team produced an initial set of files for developmental testing during SDD, but the operational mission data loads—one for each potential major geographic area of operation—are being developed, tested, and produced by a U.S. government lab, the U.S. Reprogramming Lab (USRL), located at Eglin AFB, Florida, which is operated by government personnel from the Services. The Air Force is the lead Service. These mission data loads will be used for operational testing and fielded aircraft, including the Marine Corps and Air Force IOC aircraft. The testing of the USRL mission data loads is an operational test activity, as was arranged by the Program Office after the restructure that occurred in 2010.

- Significant deficiencies exist in the USRL that preclude efficient development of effective mission data loads. Unless remedied, these deficiencies will cause significant limitations for the F-35 in combat against existing threats. These deficiencies apply to multiple potential theaters of operation and affect all variants and all Services.
  - In February 2012, DOT&E recommended upgrades to the USRL to overcome the significant shortfalls in the ability of the lab to provide a realistic environment for mission data load development and testing. The Department provided a total of $45 Million in resources to overcome these shortfalls, with the funding beginning in 2013. Unfortunately, due to the Program Office leadership's failure to accord the appropriate priority to implementing the required corrections, not until last year did the program move to investigate the deficiencies in the lab and build a plan for corrections, and only recently did it initiate the process of contracting for improvements, which has yet to finalize at the time of this report. The status of the Department's investment is not clear.
  - The program's belated 2014 investigation confirmed the nature and severity of the shortfalls that DOT&E identified in 2012. The analysis also identified many other gaps, some of which are even more urgent and severe than those uncovered by DOT&E three years prior. Failure to aggressively address the deficiencies results in uncertainties in the aircraft's capabilities to deal with existing threats; uncertainties that will persist until the deficiencies have been overcome and which could preclude the aircraft from being operationally effective against the challenging threats it is specifically being fielded to counter. The program planned to complete upgrades to the lab in late 2017, which will be late to need if the lab is to provide a mission data load for Block 3F tactics development and preparation for IOT&E. It is important to note that many of these deficiencies apply equally to the contractor's mission systems development labs because the government lab is essentially a copy of one of the mission system software integration test labs at the contractor facility.
  - The findings of the program's 2014 investigation include:
    - Shortfalls in the ability to replicate signals of advanced threats with adequate fidelity and in adequate numbers
    - Inability to adequately and coherently stimulate all signal receivers in F-35 mission systems
    - Receiver scan scheduling tools do not function correctly when replicating complex threats
    - Mission data file generation tools errantly combine emitter modes
    - Important emitter data are ignored by the tools, which adversely affect the quality of the mission data files
    - Inability to edit existing mission data files, a condition which requires inefficient processes to make changes where the lab technicians must reconstruct the entire mission data file set with new/corrected information
  - The program must make these modifications before the USRL is required to provide the Block 3F mission data load for tactics development and preparations for IOT&E. The program's 2014 study, while agreeing with DOT&E that significant hardware upgrades are needed, has not resulted in a plan to procure those upgrades in time for Block 3F mission data load development and verification. Despite the $45 Million budget, the program has still not designed, contracted for, and ordered the required equipment—a process that will take at least two years, not counting installation and check-out. In addition, despite the conclusions of the 2014 study by the Program Office, the program has sub-optimized the upgrades it will eventually put on contract due to budgetary constraints. Procuring only a limited number of signal generators would leave the USRL with less capability than the F-35 Foreign Military Sales Reprogramming Lab. This decision constitutes a critical error on the part of the program's leadership.
  - An investment greater than the $45 Million recommended by DOT&E in 2012 is needed to address all necessary hardware and software corrections to the lab. Although over three years have already been lost to inaction, the Program Office still does not plan to put Block 3F upgrades to the USRL on contract until late in 2016. The program recently briefed that once the equipment is finally ordered in 2016, it would take at least two years for delivery, installation, and check-out—after IOT&E begins (according to the current schedule of the program of record). This results in a high risk to both a successful IOT&E and readiness for combat. When deficiencies were first identified in 2012, there was time to make early corrections and avoid, or at least significantly reduce, the risk that is now at hand. Instead, due to the failure of leadership, the opposite has occurred.
- The USRL staff submitted a plan in 2013 for the operational testing of the Block 2B mission data loads, which was amended by the test team per DOT&E instructions, and approved by DOT&E. The plan includes multi-phased lab testing followed by a series of flight tests before release to operational aircraft.
- Because the program elected to delay the arrival of the USRL equipment several years, a significant amount of schedule pressure on the development and testing of the Block 2B mission data loads developed in 2015. The USRL staff was required to truncate the planned testing, forgoing important steps in mission data load development, optimization, and verification, and instead, apply its resources and manpower to providing a limited mission data load in June 2015 for the Marine Corps IOC. The limited extent of lab and flight testing that occurred creates uncertainties in F-35 combat effectiveness that must be taken into consideration by fielded operational units until the lab is able to complete optimization and testing of a Block 2B mission data load in

accordance with the plan. This additional work is planned to occur in early 2016.
- A similar sequence of events may occur with the Air Force IOC, planned for August 2016 with Block 3i. Mission data loads must be developed to interface with the system data load, and they are not forwards or backwards compatible. Block 3i mission data load development and testing will occur concurrently with completion of Block 2B mission data loads, creating pressure in the schedule as the lab configuration will have to be changed to accommodate the development and testing of both blocks.

Weapons Integration

Block 2B

- The program terminated Block 2B developmental testing for weapons integration in December 2015 after completing 12 of the 15 planned WDA events. The program had planned to complete all 15 WDA events by the end of October 2014, but delays in implementing software fixes for deficient performance of the Electro-Optical Targeting System (EOTS), radar, fusion, Multi-function Advanced Data Link (MADL), Link 16 datalink, and electronic warfare mission systems slowed progress.
  - All three of the deferred events are AIM-120 missile shot scenarios. The program deferred one of the remaining events to Block 3i, awaiting mission systems updates for radar deficiencies. The program completed that missile shot scenario in September 2015 with Block 3i software. The program deferred the other two events to Block 3F due to mission systems radar, fusion, and electronic warfare system deficiencies. Fixes to Block 3F capability are needed in order to execute these scenarios.
  - Eleven of the 12 completed events required developmental test control team intervention to overcome system deficiencies to ensure a successful event (acquire and identify target, engage with weapon). The program altered the event scenarios to make them less challenging for three of these, as well as the twelfth event, specifically to work around F-35 system deficiencies (e.g., changing target spacing or restricting target maneuvers and countermeasures). The performance of the Block 2B configured F-35 in combat will depend in part on the degree to which the enemy conforms to these narrow scenarios, which is unlikely, and enables the success of the workarounds necessary for successful weapons engagement.
- Mission systems developmental testing of system components required neither operation nor full functionality of subsystems that were not a part of the component under test. The developmental test teams designed the individual component tests only to verify compliance with contract specification requirements rather than to test the complete find-fix-identification (ID)-track-target-engage-assess-kill chain for air-to-air and air-to-ground mission success. The test team originally designed WDA events, however, purposefully to gather weapons integration and fire-control performance using all the mission systems required to engage and kill targets in the full kill chain. WDA events, therefore, became the developmental test venue that highlighted the impact of the backlog of deficiencies created by focusing prior testing only on contract specification compliance, instead of readiness for combat.
- Each WDA event requires scenario dry-runs in preparation for the final end-to-end event to ensure the intended mission systems functionality, as well as engineering and data analysis requirements (to support the test centers and weapon vendors), are available to complete the missile shot or bomb drop. Per the approved TEMP, the preparatory and end-to-end WDA events must be accomplished with full mission systems functionality, including operationally realistic fire control and sensor performance. However, as stated above, the program executed all 12 of the Block 2B WDA events using significant procedural and technical workarounds to compensate for the deficiencies resident in the Block 2B configuration.
  - Deficiencies in the Block 2B mission systems software affecting the WDA events were identified in fusion, radar, passive sensors, identification friend-or-foe, EOTS, and the aircraft navigation model. Deficiencies in the datalink systems also delayed completion of some events. Developmental test team intervention was required from the control room to overcome deficiencies in order to confirm surface target coordinates, confirm actual air targets among false tracks, and monitor/advise regarding track stability (which could not be determined by the pilot). Overall, these deficiencies continued to delay the CY15 WDA event schedule and compromised the requirement to execute the missions with fully functional integrated mission systems. Obviously, none of this test team intervention would be possible in combat.
  - The first table on the next page shows the planned date, completion or scheduled date, and the number of weeks delayed for each of the Block 2B WDA preparatory and end-to-end events. Events completed are shown with dates in bold.
- The accumulated delays in the developmental testing WDA schedule have delayed the initiation of the operation test WDA events. The JSF Operational Test Team (JOTT) had planned on starting their full system integrated WDA event testing in July 2015; however, due to the delays in delivery of operationally representative mission systems software, coupled with delays in modifications of the operational test aircraft to the full Block 2B configuration, this operational test activity will not start until CY16. This is six months after the program and the Services fielded initial Block 2B capability, and three months later than the JOTT had planned to start.

BLOCK 2B WEAPON ACCURACY DELIVERY EVENTS							
Weapon	WDA Number	Preparatory Events			End-to-End Event		
		Planned	Completed/ *Scheduled*	Weeks Delayed	Planned	Completed/ *Scheduled*	Weeks Delayed
AIM-120	102	Sep 13	**Sep 13**	2	Oct 13	**Oct 13**	2
	112	Sep 13	**Sep 13**	3	Oct 13	**Nov 13**	3
GBU-12	113	Sep 13	**Oct 13**	3	Oct 13	**Oct 13**	0
GBU-32	115	Sep 13	**Nov 13**	6	Nov 13	**Dec 13**	3
AIM-120	108	Oct 13	**Dec 13**	7	Dec 13	**Feb 14**	12
	110	Oct 13	**Aug 13**	43	Dec 13	**Nov 14**	50
	111	Dec 13	*Deferred to Block 3F*	--	Jan 14	*Deferred to Block 3F*	--
	106	Dec 13	**Sep 14**	40	Jan 14	**Nov 14**	43
GBU-31	114	Dec 13	**May 14**	45	Feb 14	**Nov 14**	41
			Jun 14				
			Oct 14				
AIM-120	104	Feb 14	**Aug 14**	28	Mar 14	*Deferred to Block 3i*	71
			Sep 14	30			
	107	Mar 14	**Jun 14**	12	May 14	**Feb 15**	30
	101	May 14	**May 14**	17	Jun 14	**Jan 15**	26
			Sep 14				
	103	Jun 14	**Mar 14**	-4	Aug 14	**May 14**	-10
			May 14				
	109	Jul 14	**Jan 14**	-29	Sep 14	**Mar 14**	-27
	105	Sep 14	*Deferred to Block 3F*	-	Oct 14	*Deferred to Block 3F*	-

1. Some WDA events require more than one preparatory event.

Block 3i

- The program planned that Block 3i would not incorporate any new capability or fixes from the Block 2B development/fleet release. The block 3i WDA events were capability demonstrations to confirm translation of Block 2B performance to the Block 3i TR-2 hardware. The one AIM-120 missile shot scenario deferred from Block 2B was completed in September 2015.
- The table to the right shows the planned date, completion or scheduled date, and weeks delayed for each of the WDA preparatory and end-to-end events.

BLOCK 3I WEAPON ACCURACY DELIVERY EVENTS							
Weapon	WDA Number	Preparatory Events			End-to-End Event		
		Planned	Completed/ *Scheduled*	Weeks Delayed	Planned	Completed/ *Scheduled*	Weeks Delayed
AIM-120	104 (deferred from 2B)	Feb 14	**Sep 15**	82	Mar 14	**Sep 15**	78
	201	May 15	**May 15**	0	Jun 15	**Jul 15**	3
	204	Jul 15	**Jul 15**	0	Aug 15	**Sep 15**	4
GBU-12	202	May 15	**May 15**	0	May 15	**Aug 15**	11
GBU-31	203	May 15	**May 15**	0	Jun 15	**Jun 15**	0

1. Some WDA events require more than one preparatory event.

Block 3F

- The Block 3F weapons delivery plan currently contains 48 events that will test required Block 3F capabilities. Twenty-nine of these weapon profiles accommodate full Block 3F expanded envelope employment and systems integrated testing of the GBU-12, GBU-31/32 JDAM, Navy JSOW, GBU-39 SDB-1, AIM-120, and AIM-9X. Nineteen of the Block 3F WDA events test air-to-air and air-to-ground gun employment in all three variants (F-35A internal gun; F-35B and F-35C external gun pod). Including the two deferred events from Block 2B creates a total of 50 required weapons delivery accuracy events to be accomplished in approximately 15 months. These Block 3F events are more complex than the Block 2B and 3i events

because of additional capability in mission systems such as advanced geolocation, multiple weapon events, enhanced radar modes, and expanded weapons envelopes and loadouts. As will be needed in combat employment, Block 3F WDA events will require reliable and stable target tracking, full MADL shoot-list sharing, Link 16 capability, and predictable fusion performance in integrated systems operation.

- While the program has instituted several process changes in mission systems software testing, maintaining the necessary WDA event tempo to complete the Block 3F events will be extremely challenging. The current build plans for each Block 3F software version show that the most challenging scenarios will not be possible until the final software version. This increases the likelihood of late discoveries of deficiencies, as occurred during Block 2B WDA testing.
- Completing the full set of Block 3F WDA events by May 2017, the planned end of Block 3F flight test according to the most recent program schedule, will require an accomplishment rate of over 3 events per month, more than 3 times the rate observed in completing the 12 Block 2B WDA events (approximately 0.8 events per month). Extending by two months to the end of July 2017, as has recently been briefed by the Program Office as the end of SDD flight test, is still unrealistic. Unless the accomplishment rate increases over the rate during the Block 2B testing period, completing all Block 3F WDA events will not occur until November 2021. In order to meet the schedule requirements for weapon certification, the Program Office has identified 10 high priority WDA events for the F-35A and 5 events for the F-35B and F-35C that must be accomplished during Block 3F developmental testing. The program plans to accomplish the remaining 35 events as schedule margin allows. The overall result of the WDA events must be that the testing yields sufficient data to evaluate Block 3F capabilities. Deleting numerous WDA events places successful IOT&E and combat capability at significant risk.

Static Structural and Durability Testing

- Structural durability testing of all variants using full-scale test articles is ongoing, with each having completed at least one full lifetime (8,000 equivalent flight hours, or EFH). All variants are scheduled to complete three full lifetimes of testing before the end of SDD; however, complete teardown, analyses, and Damage Assessment and Damage Tolerance reporting is not scheduled to be completed until August 2019. The testing on all variants has led to discoveries requiring repairs and modification to production designs and retrofits to fielded aircraft.
- F-35A durability test article (AJ-1) completed the second lifetime of testing, or 16,000 EFH in October 2015. While nearing completion of the second lifetime, testing was halted on August 13, 2015, when strain gauges on the forward lower flange of FS518, an internal wing structure, indicated deviations from previous trends. Inspections showed cracking through the thickness of the flange, so the program designed an interim repair to allow testing to continue and finish the second lifetime.
- F-35B durability test article (BH-1) completed 11,915 EFH by August 13, 2015, which is 3,915 hours (48.9 percent) into the second lifetime. The program completed the 11,000 hour data review on August 5, 2015.
  - Two main wing carry-through bulkheads, FS496 and FS472, are no longer considered production-representative due to the extensive existing repairs. The program plans to continue durability testing, repairing the bulkheads as necessary, through the second lifetime (i.e., 8,001 through 16,000 EFH) which is projected to be complete in mid-2016.
  - Prior to CY15, testing was halted on September 29, 2013, at 9,056 EFH, when the FS496 bulkhead severed, transferred loads to, and caused cracking in the adjacent three bulkheads (FS518, FS472, and FS450). The repairs and an adequacy review were completed on December 17, 2014, when the program determined that the test article could continue testing. Testing restarted on January 19, 2015, after a 16-month delay.
  - The program determined that several of the cracks discovered from the September 2013 pause at 9,056 EFH were initiated at etch pits. These etch pits are created by the etching process required prior to anodizing the surface of the structural components; anodizing is required for corrosion protection. Since the cracks were not expected, the program determined that the etch pits were more detrimental to fatigue life than the original material design suggested. The program is currently developing an analysis path forward to determine the effect on the overall fatigue life.
  - Discoveries requiring a pause in testing during CY15 include:
    - Cracking in the left- and right-hand side aft boom closeout frames, which are critical structural portions at the very aft of the airframe on each side of the engine nozzle, at 9,080 EFH. The cracks were not predicted by modeling and required a three-week pause in testing for repair, which consisted of a doubler (i.e., additional supporting element) as an interim fix to allow testing to continue. Designs for retrofitting and cut-in for production are under development.
    - Damage to a significant number of Electro-Hydraulic Actuator System (EHAS) fasteners and grommets at 9,333 EFH. The EHAS drives the aircraft control surfaces based on the direction and demand input by the pilot through the control stick.
    - Inspections in April 2015 revealed that cracks at four previously-identified web fastener holes near the trunnion lug of the FS496 bulkhead, a component integral to the bulkhead that supports the attachment of the main landing gear to the airframe, had grown larger. FS496 was previously identified as a life-limited part and will be modified as part of the life-limited modification plans for production aircraft in Lots 1

    - through 8, and a new production design cut into Lot 9 and later lot aircraft.
    - Failure of the left 3-Bearing Swivel Nozzle door uplock in April 2015; requiring replacement prior to restarting testing in May 2015.
    - Crack indication found at two fastener holes on the left side keel.
    - Crack reoccurrence at the Station 3 pylon at 10,975 EFH.
    - Cracks on the transition duct above the vanebox, a component of the lift fan, discovered in August 2015, requiring the jacks that transmit loads to the duct to be disconnected to allow cycling of the rest of the test article to continue.
    - During the repair activity in September 2015, a crack was discovered in a stiffener on the right-hand side of the mid-fairing longeron.
  - Testing has been paused since August 2015 to allow replacement and repair activities; a process estimated to take five months. Testing is planned to restart in January 2016.
- Testing of the F-35C durability test article (CJ-1) was paused at the end of October 2015 when cracks were discovered in both sides (i.e., the right- and left-hand sides) of one of the front wing spars after 13,731 EFH of testing. The Program Office considers this to be a significant finding, since the wing spar is a primary structural component and the cracking was not predicted by finite element modeling. Root cause analysis and options for repairing the test article are under consideration as of the writing of this report. Testing of the second lifetime (16,000 EFH) was scheduled to be completed by February 1, 2016, but discoveries and associated repairs over the last year put this testing behind schedule.
  - Additional discoveries since October 2014 include:
    - Cracking of the BL12 longerons, left and right sides, at 10,806 EFH, required a 10-week pause in testing for repairs. The effect to production and retrofit is still to be determined.
    - Cracks on the FS518 wing carry-through lower bulkhead at 11,770 EFH in May 2015.
    - A crack at butt line 23 on the right hand side of the FS496 bulkhead (initiating at a fastener hole).
    - A crack was discovered during the Level-2 inspection in the FS472 wing carry-through bulkhead after the completion of 12,000 EFH in June 2015. Repair work was completed prior to restarting testing in late August.
- The program plans to use Laser Shock Peening (LSP), a mechanical process designed to add compressive residual stresses in the materials, in an attempt to extend the lifetime of the FS496 and FS472 bulkheads in the F-35B. The first production line cut-in of LSP would start with Lot 11 F-35B aircraft. Earlier Lot F-35B aircraft will undergo LSP processing as part of a depot modification. Testing is proceeding in three phases: first, coupon-level testing to optimize LSP parameters; second, element-level testing to validate LSP parameters and quantify life improvement; and third, testing of production and retrofit representative articles to verify the service life improvements. All three phases are in progress, with full qualification testing scheduled to be completed in October 2017.

Verification Simulation (VSim)

- Due to inadequate leadership and management on the part of both the Program Office and the contractor, the program has failed to develop and deliver an adequate Verification Simulation (VSim) for use by either the developmental test team or the JSF Operational Test Team (JOTT), as has been planned for the past eight years and is required in the approved TEMP. Neither the Program Office nor the contractor has accorded VSim development the necessary priority, despite early identification of requirements by the JOTT, $250 Million in funding added after the Nunn-McCurdy-driven restructure of the program in 2010, warnings that development and validation planning were not proceeding in a productive and timely manner, and recent (but too late) intense senior management involvement. As a result, VSim development is another of several critical paths to readiness for IOT&E.
- The Program Office's subsequent decision in September 2015 to move the VSim to a Naval Air Systems Command (NAVAIR) proposal for a government-led Joint Simulation Environment (JSE) will not result in a simulation with the required capabilities and fidelity in time for F-35 IOT&E. Without a high-fidelity simulation, the F-35 IOT&E will not be able to test the F-35's full capabilities against the full range of required threats and scenarios. Nonetheless, because aircraft continue to be produced in substantial quantities (essentially all of which require modifications and retrofits before being used in combat), the IOT&E must be conducted without further delay to demonstrate F-35 combat effectiveness under the most realistic conditions that can be obtained. Therefore, to partially compensate for the lack of a simulator test venue, the JOTT will now plan to conduct a significant number of additional open-air flights during IOT&E, in addition to those previously planned. In the unlikely event a simulator is available in time for IOT&E, the additional flights would not be flown.
- VSim is a man-in-the-loop, mission systems software-in-the-loop simulation developed to meet the operational test requirements for Block 3F IOT&E. It is also planned by the Program Office to be used as a venue for contract compliance verification prior to IOT&E. It includes an operating system in which the simulation runs, a Battlespace Environment (BSE), models of the F-35 and other supporting aircraft, and models of airborne and ground-based threats. After reviewing a plan for the government to develop VSim, the Program Office made the decision in 2011 to have the contractor develop the simulation instead.
- The Program Office began a series of tests in 2015 to ensure that the simulation was stable and meeting the reduced set of requirements for limited Block 2B operational activities. Though the contractor's BSE and operating system had improved since last year, deficiencies in specific F-35 sensor

models and the lack of certain threat models would have limited the utility of the VSim for Block 2B operational testing, had it occurred. The program elected instead to provide a VSim capability for limited tactics development. The Air Force's Air Combat Command, which is the lead for developing tactics in coordination with the other services, planned two VSim events for 2015.
  - Air Combat Command completed the first event in July which included one- and two-ship attack profiles against low numbers of enemy threats. This event was planned to inform the tactics manual that will support IOT&E and the operational units, but validation problems prevented detailed analysis of results (i.e., minimum abort ranges).
  - The second event, led by the JOTT with Marine Corps pilots flying, was completed in October 2015 for the limited use of data collection and mission rehearsals to support test preparation for IOT&E. While valuable lessons were learned by the JOTT and the Marine Corps, the lack of accreditation made it impossible for the JOTT to make assessments of F-35 system performance.
- Verification, Validation, and Accreditation (VV&A) activity completely stalled in 2015 and did not come close to making the necessary progress towards even the reduced set of Block 2B requirements.
  - Less than 10 percent of the original validation points were collected from flight test results, and a majority of those showed significant deviations from installed system performance. The vehicle systems model, which provides the aircraft performance and flying qualities for the simulation, and certain weapons and threats models, were generally on track. However, mission systems, composed of the sensor models and fusion, had limited validation data and were often unstable or not tuned, as required, to represent the installed mission systems performance, as measured in flight-testing.
  - The contractor and program management failed to intervene in time to produce a simulation that met even the reduced set of user requirements for Block 2B and, although they developed plans to increase VV&A productivity, they did not implement those plans in time to make a tangible difference by the time of this report. As the focus changed to Block 3F and IOT&E, the contractor and the Program Office made little progress; no VV&A plans materialized, data that had been collected were still stalled at the test venues awaiting review and release, alternative data sources had not yet been identified for new threats, and contract actions needed to complete VSim for Block 3F IOT&E were not completed.
- In September 2015, the Program Office directed a change in responsibility for VSim implementation, reassigning the responsibility from the contractor, Lockheed Martin, to a government team led primarily by NAVAIR. This was triggered by a large increase in the contractor's prior proposed cost to complete VSim, a cost increase which included work that should already have been completed in Block 2B and mitigations intended to overcome prior low productivity. The path to provide an adequate validation of the simulation for Block 3F IOT&E carries risk, regardless of who is responsible for the implementation of the simulation. That risk was increased by the Program Office's decision to move the simulation into a government controlled (non-proprietary) facility and simulation environment. After analyzing the steps needed to actually implement the Program Office's decision to move the VSim to the JSE, it is clear that the JSE will not be ready, with the required capabilities and fidelity, in time for F-35 IOT&E in 2018. It is also clear that both NAVAIR and the Program Office significantly underestimated the scope of work, the cost, and the time required to replace Lockheed Martin's proprietary BSE with the JSE while integrating and validating the required high-fidelity models for the F-35, threats, friendly forces, and other elements of the combat environment.
  - The JSE proposal abandons the BSE that is currently running F-35 Block 2B.
  - The JSE proposal does not address longstanding unresolved issues with VSim, including the ability of the program to produce validation data from flight test, to analyze and report comparisons of that data with VSim performance, and to "tune" VSim to match the installed system performance demonstrated in flight-testing.
  - While the JSE might eventually reach the required level of fidelity, it will not be ready in time for IOT&E since the government team must re-integrate into the JSE the highly detailed models of the F-35 aircraft and sensors, and additional threat models that the contractor has "hand-built" over several years.
  - The current VSim F-35 aircraft and sensor models interact directly with both the BSE and the current contractor's operating system. A transition to the JSE will require a re-architecture of these models before they can be integrated into a different environment. The need to do this, along with the costs of contractor support for the necessary software models and interfaces, will overcome the claims of cost savings in NAVAIR's proposal.
  - The highly integrated and realistic manned "red air" simulations in VSim, which were inherited from other government simulations, cannot be replicated in the limited time remaining before IOT&E.
  - The large savings estimates claimed by NAVAIR as the basis for their JSE proposal are not credible, and, the government team's most recent estimates for completion of the JSE have grown substantially from its initial estimate. Nearly all the costs associated with completing VSim in its current form would also transfer directly to JSE, with significant additional delays and risk. Any potential savings in the remaining costs from government-led integration are far outweighed by the additional costs associated with upgrading or building new facilities, upgrading or replacing the BSE, re-hosting the F-35 on government infrastructure, and paying Lockheed Martin to build interfaces between their F-35 models and the JSE.

- The JSE proposal adds significant work and schedule risk to the contractor's ability to deliver a functioning and validated Block 3F aircraft model in time for IOT&E. Besides being required to complete integration of Block 3F capabilities, validate the simulation, and tune the sensor models to installed system performance, the contractor must also simultaneously assist the government in designing new interfaces and re-hosting the F-35 and hand-built threat models into the JSE to all run together in real-time so they can be validated and accredited.
- Abandoning VSim also affects the F-22 program, as the various weapons and threat models being developed were planned to be reused between the two programs. The upcoming F-22 Block 3.2B IOT&E depends on the BSE currently in development.

• For the reasons listed above, the Program Office's decision to pursue the NAVAIR-proposed JSE, without the concurrence of the operational test agencies (OTAs) or DOT&E, will clearly not provide an accredited simulation in time for F-35 IOT&E, and the OTAs have clearly expressed their concerns regarding the risks posed to the IOT&E by the lack of VSim. Nonetheless, so as not to delay IOT&E any further while substantial numbers of aircraft are being produced, DOT&E and the OTAs have agreed on the need to now plan for the F-35 IOT&E assuming a simulator will not be available. This will require flying substantial additional open-air flights for tactics development, mission rehearsal, and evaluation of combat effectiveness relative to previous plans for using VSim. Even with these additional flights, some testing previously planned against large-scale, real-world threat scenarios in VSim will no longer be possible.

Live Fire Test and Evaluation (LFT&E)

F-35C Full-Scale Fuel Ingestion Tolerance Vulnerability Assessment

• The F-35 LFT&E Program completed the F-35C full-scale, fuel ingestion tolerance test series. The Navy's Weapons Survivability Laboratory (WSL) in China Lake, California, executed four tests events using the CG:0001 test article. Two of the test events were conducted with a Pratt and Whitney F-135 initial flight release (IFR)-configured engine installed in the aircraft. A preliminary review of the results indicates that:
  - The F135 IFR-configured engine is tolerant of fuel ingestion caused by single missile-warhead fragment impacts in the F1 fuel tank. The threat-induced fuel discharge into the engine inlet caused temporary increases in the nominal engine temperature, but did not result in any engine stalls or long-term damage.
  - Missile fragment-induced damage is consistent with predictions and the tanks are tolerant of single-fragment impacts. The threat-induced damage to the F1 fuel tank caused fuel leak rates that are consistent with tests conducted in FY07 using flat panels.

PAO Shut-Off Valve

• The program has not provided an official decision to reinstate this vulnerability reduction feature. There has been no activity on the development of the PAO-shut-off valve technical solution to meet criteria developed from 2011 live fire test results. As stated in several previous reports, this aggregate, 2-pound vulnerability reduction feature, if installed, would reduce the probability of pilot incapacitation, decrease overall F-35 vulnerability, and prevent the program from failing one of its vulnerability requirements.

Fuel Tank Ullage Inerting System and Lightning Protection

• The program verified the ullage inerting design changes, including a new pressurization and ventilation control valve, wash lines to the siphon tanks, and an external wash line, and demonstrated improved inerting performance in F-35B fuel system simulator tests. A preliminary data review demonstrated that the system pressurized the fuel tank with nitrogen enriched air (NEA) while maintaining pressure differentials within design specifications during all mission profiles in the simulator, including rapid dives. The Program Office will complete and document a detailed data review and analyses that evaluate NEA distribution and inerting uniformity between different fuel tanks and within partitioned fuel tanks.

• The program developed a computational model to predict inerting performance in the aircraft based on the F-35B simulator test results. Patuxent River Naval Air Station completed the ground inerting test on a developmental test F-35B aircraft to verify the inerting model. Preliminary analyses of the results indicate that there is good correlation between the ground inerting test and the F-35B fuel system simulator. The program will use this model, in conjunction with the completed F-35A and F-35C ground tests, to assess the ullage inerting effectiveness for all three variants. The confidence in the final design's effectiveness will have to be reassessed after the deficiencies uncovered in the aircraft ground and flight tests, including small uninerted fuel tank ullage spaces, have been fully resolved.

• When effective, ullage inerting protects the fuel tanks from not just threat-induced damage but also lightning-induced damage. The ullage inerting system does not protect any other components or systems from lightning-induced damage.

• The program has made progress completing lightning tolerance qualification testing for line-replaceable units needed to protect the remaining aircraft systems from lightning-induced currents. Lightning tolerance tests using electrical current injection tests are ongoing, and the program expects to complete the tests by 2QFY16.

Vulnerability to Unconventional Threats

• The full-up, system-level chemical-biological decontamination test on an SDD aircraft planned for 4QFY16 at Edwards AFB is supported by two risk-reduction events:

- A System Integration Demonstration of the proposed decontamination equipment and shelter was conducted on an F-16 test article during 1QFY15 at Edwards AFB to simulate both hot air chemical and hot/humid air biological decontamination operations. Extensive undesirable condensation inside the shelter and on the test article during the hot/humid air biological decontamination event indicated the need for process and shelter modifications.
- A demonstration of an improved shelter is planned for 2QFY16 to demonstrate that a modified system process and better insulated shelter can maintain adequate temperature and humidity control inside the shelter, even in a cold-weather environment.

- The test plan to assess chemical and biological decontamination of pilot protective equipment is not adequate. Compatibility testing of protective ensembles and masks has shown that the materials survive exposure to chemical agents and decontamination materials and processes, but the program has neither tested nor provided plans for testing the Helmet Mounted Display Systems (HMDS) currently being fielded. Generation II HMDS compatibilities were determined by analysis, comparing HMDS materials with those in an extensive DOD aerospace materials database. A similar analysis is planned for the Generation III HMDS design. However, even if material compatibilities were understood, there are no plans to demonstrate a process that could adequately decontaminate either HMDS from chemical and biological agents.
- The Joint Program Executive Office for Chemical and Biological Defense approved initial production of the F-35 variant of the Joint Service Aircrew Mask (JSAM-JSF) during 1QFY16. This office and the F-35 Joint Program Office are integrating the JSAM-JSF with the Helmet-Mounted Display, which is undergoing Safety of Flight testing.
- The Navy evaluated an F-35B aircraft to the EMP threat level defined in MIL-STD-2169B. Follow-on tests on other variants of the aircraft, including a test series to evaluate any Block 3F hardware/software changes, are planned for FY16.

Gun Ammunition Lethality and Vulnerability

- The program completed the terminal ballistic testing of the PGU-47 APEX round against a range of target-representative material plates and plate arrays. Preliminary test observations indicated expected high levels of fragmentation when passing through multiple layer, thin steel or aluminum targets, along with a deep penetration through more than an inch of rolled homogeneous armor steel by the nose of the penetrator. The program will evaluate the effect of these data on the ammunition lethality assessment.
- The 780th Test Squadron at Eglin AFB has completed the ground-based Frangible Armor Piercing (FAP) and initiated the PGU-32 lethality tests. The APEX rounds will be tested in FY16 against a similar range of targets, including armored and technical vehicles, aircraft, and personnel in the open. Ground-based lethality tests for the FAP showed expected high levels of penetration against all targets, with slightly less internal target fragmentation than originally anticipated, and low levels of lethality against personnel in the open (unless impacted directly). The program will determine the effect of these data on the ammunition lethality assessment.
- Per the current mission systems software schedule, the weapons integration characterization of the gun and sight systems will not be ready for the air-to-ground gun strafe lethality tests until 1QFY17. Strafing targets will include a small boat, light armored vehicle and technical vehicle (pickup truck), one each for each round type tested. Because the APEX round is not currently a part of the program of record, funding for developmental or operational air-to-ground flight testing of the APEX round is not planned at this time.

Operational Suitability

- Operational suitability of all variants continues to be less than desired by the Services, and relies heavily on contractor support and workarounds that would be difficult to employ in a combat environment. Almost all measures of performance have improved over the past year, but most continue to be below their interim goals to achieve acceptable suitability by the time the fleet accrues 200,000 flight hours, the benchmark set by the program and defined in the Operational Requirements Document (ORD) for the aircraft to meet reliability and maintainability requirements. This level of maturity is further stipulated as 75,000 flight hours for the F-35A, 75,000 flight hours for the F-35B, and 50,000 flight hours for the F-35C.
  - Aircraft fleet-wide availability averaged 51 percent for 12 months ending October 2015, compared to a goal of 60 percent.
  - Availability had been in mid-30s to low-40s percent for the 2-year period ending September 2014. Monthly availability jumped 12 percent to 51 percent by the end of October 2014, one of the largest month-to-month spikes in program history, and then peaked at 56 percent in December 2014. Since then it has remained relatively flat, centering around 50 percent, although it achieved 56 percent again in September 2015. The significant improvement that occurred around October 2014 was due in roughly equal measure to a reduction in the time aircraft were undergoing maintenance and a reduction in the time aircraft were awaiting spare parts from the supply system. The aircraft systems that showed the greatest decreases (improvement) in maintenance downtime during the month of October 2014 were the engine and the ejection seat.
  - It would be incorrect to attribute the still-low availability the F-35 fleet has exhibited in 2015, specifically the failure to meet the goal of 60 percent availability, solely to issues stemming from the additional engine inspections required since the June 2014 engine failure on AF-27. Availability did drop immediately after the engine failure, partly due to these inspections, but has since recovered to pre-engine failure levels, and improved only slightly from there when considered as a long-term trend. For the three months

ending October 2015, the fleet was down for the 3rd Stage Integrally Bladed Rotor (IBR) inspections—required due to the engine failure—less than 1 percent of the time.

- Measures of reliability that have ORD requirement thresholds have improved since last year, but eight of nine measures are still below program target values for the current stage of development, although two are within 5 percent of their interim goal; one—F-35B Mean Flight Hours Between Maintenance Events (Unscheduled)—is above its target value. In addition to the nine ORD metrics, there are three contract specification metrics, Mean Flight Hour Between Failures scored as "design controllable" (one for each variant). Design controllable failures are equipment failures due to design flaws considered to be the fault of the contractor, such as components not withstanding stresses expected to be found in the normal operational environment. It does not include failures caused by improper maintenance, or caused by circumstances unique to flight test. This metric continues to see the highest rate of growth, and for this metric all three variants are currently above program target values for this stage in development.
- Although reliability, as measured by the reduced occurrence of design controllable failures, has shown strong growth, this has only translated into relatively minor increases in availability for several reasons. These reasons include the influences of a large amount of time spent on scheduled maintenance, downtime to incorporate required modifications, waiting longer for spare parts than planned, and potentially longer-than-expected repair times, especially if units have to submit Action Requests (ARs) for instructions on repairs with no written procedures yet available. Finally, aircraft in the field become unavailable for failures not scored as design controllable as well. All of these factors affect the final availability rate the fleet achieves at any given time, in addition to the effect of improved reliability.
- F-35 aircraft spent 21 percent more time than intended down for maintenance, and waited for parts from supply for 51 percent longer than the program targeted. At any given time, from 1-in-10 to 1-in-5 aircraft were in a depot facility or depot status for major re-work or planned upgrades, and of the fleet that remained in the field, on average, only half were able to fly all missions of even a limited capability set.

• Accurate suitability measures rely on adjudicated data from fielded operating units. A Joint Reliability and Maintainability Evaluation Team (JRMET), composed of representatives from the Program Office, the JOTT, the contractor (Lockheed Martin), and Pratt and Whitney (for engine records), reviews maintenance data to ensure consistency and accuracy for reporting measures; government representatives chair the team. However, the Lockheed Martin database that stores the maintenance data, known as the Failure Reporting and Corrective Action System (FRACAS), is not in compliance with U.S. Cyber Command information assurance policies implemented in August 2015. Because of this non-compliance, government personnel have not been able to access the database via government networks, preventing the JRMET from holding the planned reviews of maintenance records. As a result, the Program Office has not been able to produce Reliability and Maintainability (R&M) metrics from JRMET-adjudicated data since the implementation of the policy. The most current R&M metrics available for this report are from the three-month rolling window ending in May 2015. The Program Office is investigating workarounds to enable the JRMET to resume regular reviews of maintenance records until Lockheed Martin can bring the FRACAS database into compliance.

F-35 Fleet Availability

• Aircraft availability is determined by measuring the percent of time individual aircraft are in an "available" status, aggregated over a reporting period (e.g., monthly). The program assigns aircraft that are not available to one of three categories of status: Not Mission Capable for Maintenance (NMC-M); Not Mission Capable for Supply (NMC-S); and Depot status.
  - Program goals for these "not available" categories have remained unchanged since 2014, at 15 percent for NMC-M, 10 percent for NMC-S, and 15 percent of the fleet in depot status. Depot status is primarily for executing the modification program to bring currently fielded aircraft closer to their expected airframe structural lifespans of 8,000 flight hours and to incorporate additional mission capability. The majority of aircraft in depot status are located at dedicated depot facilities for scheduled modification periods that can last several months, and they are not part of the operational or training fleet during this time. A small portion of depot status can occur in the field when depot field teams conduct a modification at a main operating base, or affect repairs beyond the capability of the local maintenance unit.
  - These three "not available" category goals sum to 40 percent, leaving a targeted fleet-wide goal of 60 percent availability for 2015. At the time of this report, this availability goal extended uniformly to the individual variants, with each variant having a target of 60 percent availability as well. For a period during 2015, however, the program set variant-specific availability goals to account for the fact that the variants were cycling through the depots at different rates. A particularly large portion of the F-35B fleet was in depot in early 2015 to prepare aircraft for Marine Corps IOC declaration, for example. From February to August 2015, the variant-specific availability goals were reported as 65 percent for the F-35A, 45 percent for the F-35B, and 70 percent for the F-35C, while the total fleet availability goal remained 60 percent.

• Aircraft monthly availability averaged 51 percent for the 12-month period ending October 2015 in the training and

operational fleets. This is an increase over the 37 percent availability reported in both of the previous two DOT&E Annual Reports from FY13 and FY14.

- However, in no month did the fleet exceed its goal of 60 percent availability. In several months, individual variants beat either the 60 percent goal, or their at-the-time variant-specific goal. The F-35A achieved 63 percent availability in December 2014, but never surpassed 65 percent. The F-35C was above 60 percent availability from November 2014 to June 2015, and again in September and October 2015, and was above 70 percent in four of these months. The F-35B was above 45 percent availability in only one month, October 2015, when it achieved 48 percent. This was after the program returned its variant-specific availability target to 60 percent.
- The table below summarizes aircraft availability rates by operating location for the 12-month period ending October 2015. The first column indicates the average availability achieved for the whole period, while the maximum and minimum columns represent the range of monthly availabilities reported over the period. The number of aircraft assigned at the end of the reporting period is shown as an indicator of potential variance in the rates. Sites are arranged in order of when each site began operation of any variant of the F-35, and then arranged by variant for sites operating more than one variant. In February 2015, the Marine Corps terminated operations of the F-35B at Eglin AFB and transferred the bulk of the aircraft from that site to Marine Corps Air Station (MCAS) Beaufort, South Carolina. As a result, the number of F-35B aircraft assigned to Eglin AFB as of September 2015 was zero.

F-35 AVAILABILITY FOR 12-MONTH PERIOD ENDING OCTOBER 2015[1]

Operational Site	Average	Maximum	Minimum	Aircraft Assigned[2]
Whole Fleet	51%	56%	46%	134
Eglin F-35A	55%	62%	39%	25
Eglin F-35B[3]	43%	48%	26%	0
Eglin F-35C	66%	79%	57%	17
Yuma F-35B	39%	62%	16%	17
Edwards F-35A	32%	66%	17%	8
Edwards F-35B[4]	19%	27%	0%	6
Nellis F-35A	51%	77%	33%	10
Luke F-35A	62%	75%	50%	30
Beaufort F-35B[5]	46%	60%	24%	18
Hill F-35A[6]	80%	81%	79%	3

1. Data do not include SDD aircraft.
2. Aircraft assigned at the end of October 2015.
3. Eglin AFB F-35B ended operations in February 2015.
4. Edwards AFB F-35B operational test operations began in October 2014.
5. Beaufort MCAS F-35B operations began in July 2014.
6. Hill AFB F-35A operations began September 2015.

  - Statistical trend analysis of the monthly fleet availability rates from August 2012 through October 2015 showed a weak rate of improvement of approximately 5 percent growth per year over this period, but the growth was not consistent. For example, from August 2012 through September 2014, availability was relatively flat and never greater than 46 percent, but from September 2014 through December 2014, it rose relatively quickly month-on-month to peak at 56 percent in December. Availability then dropped a bit, and remained near 50 percent through October 2015 with no increasing trend toward the goal of 60 percent.
  - Due to concurrency, the practice of producing operational aircraft before the program has completed development and finalized the aircraft design, the Services must send the current fleet of F-35 aircraft to depot facilities to receive modifications that have been designed since they were originally manufactured. Some of these modifications are driven by faults in the original design that were not discovered until after production had started, such as major structural components that break due to fatigue before their intended lifespan, and others are driven by the continuing improvement of the design of combat capabilities that were known to be lacking when the aircraft were first built. This "concurrency tax" causes the program to expend resources to send aircraft for major re-work, often multiple times, to keep up with the aircraft design as it progresses. Since System Development and Demonstration (SDD) will continue to 2017, and by then the program will have delivered nearly 200 aircraft to the U.S. Services in other than the 3F configuration, the depot modification program and its associated concurrency burden will be with the Services for years to come.
  - Sending aircraft to depot facilities for several months at a time to bring them up to Block 2B capability and life limits, and eventually to 3F configuration, reduces the number of aircraft at field sites and thus decreases fleet availability. For the 12-month period ending in October 2015, the proportion of fleet in depot status averaged 16 percent. The depot percentage generally increased slowly at first, reaching a maximum value of 19 percent for the month of May 2015, and then started to decline around summer 2015. The depot inductions were largely in support of modifying aircraft to the Block 2B configuration for the Marine Corps IOC declaration at the end of July 2015.
  - Current program plans indicate the proportion of the fleet in depot will remain between 10 and 15 percent throughout CY16. Projections of depot rates beyond 2016 are difficult, since testing and development are ongoing. The program does not yet know the full suite of modifications that will be necessary to bring currently produced aircraft up to the envisioned final Block 3F configuration.
  - To examine the suitability performance of fielded aircraft, regardless of how many are in the depot, the program reports on the Mission Capable and Full Mission Capable (FMC) rates for the F-35 fleet. The Mission Capable rate represents the proportion of the fleet that is not in depot status and that is ready to fly any type of mission (as

opposed to all mission types). This rate includes aircraft that are only capable of flying training flights, however, and not necessarily a combat mission. Aircraft averaged 65 percent for the 12-month window considering all variants.

- The FMC rate calculates only the proportion of aircraft not in depot status that are capable of flying all assigned missions and can give a better view into the potential combat capability available to the field. It averaged 46 percent for the 12-month window considering all variants, but started to drop steadily from a peak of 62 percent achieved in December 2014, reaching a minimum value of 32 percent in October 2015. The rate declined for 8 of the 10 months from January to October 2015.
- The monthly NMC-M rate averaged 18 percent over the period, and exhibited the most variability of the non-available status categories. The NMC-M rate started out at 17 percent in November 2014, was as high as 24 percent in August 2015, and as low as 14 percent in September 2015. The Program Office set a threshold goal of 15 percent for 2015, but the fluctuations in month-to-month rates make it difficult to determine whether the goal for NMC-M can be achieved for a sustained period.
- Modifying aircraft also affects the NMC-M rate. Squadron maintainers, instead of the depot, are tasked to complete a portion of the required modifications by accomplishing Time Compliance Technical Directives (TCTDs). The "time compliance" requirements for these directives vary, normally allowing the aircraft to be operated without the modification in the interim and permit maintenance personnel to work the directive as able. While maintainers accomplish these TCTDs, the aircraft are logged as NMC-M status. Incorporating these TCTDs will drive the NMC-M rate up (worse) until these remaining modifications are completed. Publishing and fielding new TCTDs is expected for a program under development and is needed to see improvement in reliability and maintainability.
- The NMC-S rate averaged 15 percent and showed little trend, either up or down, over the period. The NMC-S rate started at 15 percent in November 2014 and ended at 16 percent in October 2015, ranging from between 12 to 19 percent in the months between. The Program Office set a threshold goal of 10 percent for 2015, but the NMC-S trend is not currently on track to achieve this.
- Modifying aircraft also has an effect on the NMC-S rate. Parts are taken from aircraft in depot status at the dedicated modification facilities in order to provide replacements for failed parts in the field, a process known as depot cannibalization. This usually occurs when replacement parts are not otherwise available from normal supply channels or stocks of spare parts on base. With the large number of aircraft in depot status, the program may have been able to improve the NMC-S rate by using depot cannibalizations, instead of procuring more spare parts, or reducing the failure rate of parts installed in aircraft, or improving how quickly failed parts are repaired and returned to circulation. If the Services endeavor to bring all of the early lot aircraft into the Block 3F configuration, the program will continue to have an extensive modification program for several years. While this will continue to provide opportunities for depot cannibalizations during that time, once the 3F modifications are complete, there will be fewer aircraft in the depot serving as spare parts sources and more in the field requiring parts support. If demand for spare parts remains high, this will put pressure on the supply system to keep up with demand without depot cannibalization as a source.
- Low availability rates are preventing the fleet of fielded operational F-35 aircraft from achieving planned, Service-funded flying hour goals. Original Service bed-down plans were based on F-35 squadrons ramping up to a steady state, fixed number of flight hours per tail per month, allowing for the projection of total fleet flight hours.
- Since poor availability in the field has shown that these original plans were unexecutable, the Program Office has since produced "modeled achievable" projections of total fleet flight hours, basing these projections on demonstrated fleet reliability and maintainability data, as well as expectations for future improvements. The most current modeled achievable projection is from November 2014.
  - Through November 23, 2015, the fleet had flown approximately 82 percent of the modeled achievable hours. This is an improvement since October 2014, the date used in the FY14 DOT&E Annual Report, when the fleet had flown only 72 percent of modeled achievable hours, but it is still below expectation.
  - The F-35B variant has flown approximately 11 percent more hours than its modeled achievable projection, in part due to a ramped up level of flying to produce trained pilots for the Marine Corps IOC declaration.

• The following table shows by variant the planned versus achieved flight hours for both the original plans and the modeled-achievable for the fielded production aircraft through November 23, 2015.

F-35 FLEET PLANNED VS. ACHIEVED FLIGHT HOURS AS OF NOVEMBER 23, 2015

Variant	Original Bed-Down Plan Cumulative Flight Hours			"Modeled Achievable" Cumulative Flight Hours		
	Estimated Planned	Achieved	Percent Planned	Estimated Planned	Achieved	Percent Planned
F-35A	26,000	16,768	65%	22,000	16,768	76%
F-35B	14,000	12,156	87%	11,000	12,156	111%
F-35C	5,500	2,949	54%	6,000	2,949	49%
Total	45,500	31,873	70%	39,000	31,873	82%

F-35 Fleet Reliability

- Aircraft reliability assessments include a variety of metrics, each characterizing a unique aspect of overall weapon system reliability.
  - Mean Flight Hours Between Critical Failure (MFHBCF) includes all failures that render the aircraft not safe to fly, and any equipment failures that would prevent the completion of a defined F-35 mission. It includes failures discovered in the air and on the ground.
  - Mean Flight Hours Between Removal (MFHBR) gives an indication of the degree of necessary logistical support and is frequently used in determining associated costs. It includes any removal of an item from the aircraft for replacement with a new item from the supply chain. Not all removals are failures, and some failures can be fixed on the aircraft without a removal. For example, some removed items are later determined to have not failed when tested at the repair site. Other components can be removed due to excessive signs of wear before a failure, such as worn tires.
  - Mean Flight Hours Between Maintenance Event Unscheduled (MFHBME Unsch) is a useful reliability metric for evaluating maintenance workload due to unplanned maintenance. Maintenance events are either scheduled (e.g., inspections, planned removals for part life) or unscheduled (e.g. maintenance to remedy failures, troubleshooting false alarms from fault reporting or defects reported but within limits, unplanned servicing, removals for worn parts—such as tires). One can also calculate the mean flight hours between scheduled maintenance events, or total events including both scheduled and unscheduled. However, for this report, all MFHBME Unsch metrics refer to the mean flight hours between unscheduled maintenance events only, as it is an indicator of aircraft reliability and the only mean-flight-hour-between-maintenance-event metric with an ORD requirement.
  - Mean Flight Hours Between Failure, Design Controllable (MFHBF_DC) includes failures of components due to design flaws under the purview of the contractor, such as the inability to withstand loads encountered in normal operation. Failures induced by improper maintenance practices are not included.
- The F-35 program developed reliability growth projections for each variant throughout the development period as a function of accumulated flight hours. These projections are shown as growth curves, and were established to compare observed reliability with target numbers to meet the threshold requirement at maturity, defined by 75,000 flight hours for the F-35A and F-35B, and by 50,000 flight hours for the F-35C, and 200,000 cumulative fleet flight hours. In November 2013, the program discontinued reporting against these curves for all ORD reliability metrics, and retained only the curve for MFHBF_DC, which is the only reliability metric included in the JSF Contract Specification (JCS). DOT&E reconstructed the growth curves for the other metrics analytically for this report and shows them in the tables on the following page for comparison to achieved values.
- As of late November 2015, the F-35, including operational and flight test aircraft, had accumulated approximately 43,400 flight hours, or slightly below 22 percent of the total 200,000-hour maturity mark defined in the ORD. Unlike the following table, which accounts only for fielded production aircraft, the flight test aircraft are included in the fleet hours which count toward reliability growth and maturity. By variant, the F-35A had flown approximately 22,300 hours, or 30 percent of its individual 75,000-hour maturity mark; the F-35B had flown approximately 15,800 hours, or 21 percent of its maturity mark; and the F-35C had flown approximately 5,300 hours, or 11 percent of its maturity mark.
- The program reports reliability and maintainability metrics on a three-month rolling window basis. This means for example, the MFHBR rate published for a month accounts only for the removals and flight hours of that month and the two previous months. This rolling three-month window provides enough time to dampen out variability often seen in month-to-month reports, while providing a short enough period to distinguish current trends.
- The first table on the following page compares current observed and projected interim goal MFHBCF values, with associated flight hours. It shows the ORD threshold requirement at maturity and the values in the FY14 DOT&E Annual Report for reference as well.
- The following similar tables compare current observed and projected interim goals for MFHBR, MFHBME Unsch, and MFHBF_DC rates for all three variants. MFHBF_DC is contract specification, and its JCS requirement is shown in lieu of an ORD threshold.
- Note that more current data than May 2015 are not available due to the Lockheed Martin database (FRACAS) not being compliant with all applicable DOD information assurance policies mandated by U.S. Cyber Command.
- Reliability values increased for 11 of 12 metrics between August 2014 and May 2015. The only metric which decreased in value was MFHBCF for the F-35C. A more in-depth trend analysis shows, however, that MFHBCF for the F-35C is likely increasing over time, albeit erratically. The MFHBCF metric shows particularly high month-to-month variability for all variants relative to the other metrics, due to the smaller number of reliability events that are critical failures. For the F-35C in particular, the August 2014 value was well above average, considering the preceding and following months, while the May 2015 value was below average for the past year.
- Despite improvements over the last year, 8 of the 12 reliability metrics are still below interim goals, based on their reliability growth curves, to meet threshold values by maturity. Two of these eight metrics however, are within 5 percent of their goal, F-35B MFHBCF and F-35C MFHBME Unsch. The remaining four are above their growth curve interim values. Of the four metrics above their growth curve interim values, three are the contract specification metric MFHBF_DC for each variant; and for this specific metric, the program is

reporting F-35B and F-35C reliability currently at or above the threshold at maturity. The fourth metric that is above the growth curve interim value is F-35B MFHBME Unsch. This is the only one of nine ORD metrics that is above its interim growth curve value. This pattern indicates that, although reliability is improving, increases in the contract specification reliability metric are not translating into equally large improvements in the other reliability metrics, which are operational requirements that will be evaluated during IOT&E.

- The F-35B is closest to achieving reliability goals, while the F-35A is furthest. For the F-35B, two of four reliability metrics are above their growth curves, one is within 5 percent, and one is below, MFHBR. MFHBR is the only metric where all three variants are less than 95 percent of their interim goal. For the F-35A and F-35C, the only metrics above their growth goals are the contract specification metrics, MFHBF_DC. One of three F-35C ORD metrics is within 5 percent of its growth goal, and all remaining F-35A and F-35C ORD metrics are below their interim targets for this stage of development.
- The effect of lower MFHBCF values is reduced aircraft full mission capability, mission capability, and availability rates. MFHBR values lagging behind their growth targets drive a higher demand for spare parts from the supply system than originally envisioned. When MFHBME Unsch values are below expectation, there is a higher demand for maintenance manpower than anticipated.
- DOT&E updated an in-depth study of reliability growth in MFHBR and MFHBME Unsch provided in the FY14 DOT&E Annual Report. The original study examined the period from July 2012 through October 2013, and modeled reliability growth using the Duane Postulate, which characterizes growth by a single parametric growth rate. Mathematically, the Duane Postulate assesses growth rate as the slope of the best-fit line when the natural logarithm of the cumulative failure rate is plotted against the natural logarithm of cumulative flight hours. A growth rate of zero would indicate no growth, and a growth rate of 1.0 is the theoretical upper limit, indicating instantaneous growth from a system that exhibits some failures to a system that never fails. The closer the growth rate is to 1.0 the faster the growth, but the relationship between assessed growth rates is not linear, due to the logarithmic nature of the plot.

F-35 RELIABILITY: MFHBCF (HOURS)

Variant	ORD Threshold		Values as of May 31, 2015				Values as of August 2014	
	Flight Hours	MFHBCF	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBCF	Observed MFHBCF (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBCF (3 Mos. Rolling Window)
F-35A	75,000	20	15,845	16.1	10.2	63%	8,834	8.2
F-35B	75,000	12	11,089	9.2	8.7	95%	7,039	7.5
F-35C	50,000	14	3,835	10.0	7.4	74%	2,046	8.3

F-35 RELIABILITY: MFHBR (HOURS)

Variant	ORD Threshold		Values as of May 31, 2015				Values as of August 2014	
	Flight Hours	MFHBR	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBR	Observed MFHBR (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBR (3 Mos. Rolling Window)
F-35A	75,000	6.5	15,845	5.3	4.7	89%	8,834	3.1
F-35B	75,000	6.0	11,089	4.6	3.9	85%	7,039	2.5
F-35C	50,000	6.0	3,835	4.3	3.4	79%	2,046	2.3

F-35 RELIABILITY: MFHBME Unsch (HOURS)

Variant	ORD Threshold		Values as of May 31, 2015				Values as of August 2014	
	Flight Hours	MFHBME Unsch	Cumulative Flight Hours	Interim Goal to Meet ORD Threshold MFHBME Unsch	Observed MFHBME Unsch (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBME Unsch (3 Mos. Rolling Window)
F-35A	75,000	2.0	15,845	1.60	1.18	74%	8,834	0.85
F-35B	75,000	1.5	11,089	1.15	1.32	115%	7,039	0.96
F-35C	50,000	1.5	3,835	1.02	1.00	98%	2,046	0.84

F-35 RELIABILITY: MFHBF_DC (HOURS)

Variant	JCS Requirement		Values as of May 31, 2015				Values as of August 2014	
	Flight Hours	MFHBF_DC	Cumulative Flight Hours	Interim Goal to Meet JCS Requirement MFHBF_DC	Observed MFHBF_DC (3 Mos. Rolling Window)	Observed Value as Percent of Goal	Cumulative Flight Hours	Observed MFHBF_DC (3 Mos. Rolling Window)
F-35A	75,000	6.0	15,845	4.6	4.8	104%	8,834	4.0
F-35B	75,000	4.0	11,089	2.9	4.3	148%	7,039	3.5
F-35C	50,000	4.0	3,835	2.6	4.0	154%	2,046	3.6

For example, a growth rate of 0.4 would indicate reliability growth much higher than twice as fast as a growth rate of 0.2.

- The updated analysis extended the period examined from July 2012 through May 2015. The analysis investigated only the F-35A and F-35B variants due to the still low number of flight hours on the F-35C. The study evaluated the current growth rate, then, using that rate, projected the reliability metric to the value expected at maturity.
- The study also evaluated the growth rate needed to meet the ORD threshold value at maturity from the current observed value of the reliability metric. The first table below shows the results of this updated study, along with the growth rates determined through October 2013 from the original study for comparison.
- The currently exhibited growth rates for three of the evaluated metrics are faster than the growth rates exhibited through October 2013. The growth rate for F-35A MFHBME Unsch reduced slightly. For both F-35A metrics and for F-35B MFHBR, the growth rate is still too low to meet the ORD threshold by maturity. The analyses project that if the current growth rate holds constant, the F-35A MFHBR metric will achieve within 90 percent of its requirement, while F-35B MFHBME Unsch will significantly exceed its requirement. DOT&E does not expect the F-35B MFHBME Unsch growth to sustain its current rate out through 75,000 flight hours, but there is plenty of margin for the rate to drop and still exceed the requirement by maturity.

Metric	Variant	May 2015 Value	Current Growth Rate from Duane Postulate	Projected Value at 75,000 Flight Hours	ORD Threshold	Projected Value as % ORD Threshold	October 2013 Growth Rate from Duane Postulate	Growth Rate Needed to Meet ORD
MFHBR	F-35A	4.7	0.204	6.0	6.5	93%	0.129	0.228
	F-35B	3.9	0.243	4.8	6.0	81%	0.210	0.297
MFHBME	F-35A	1.18	0.142	1.34	2.0	67%	0.162	0.281
	F-35B	1.32	0.427	2.74	1.5	183%	0.347	0.244

- The above growth rates were calculated with around 16,000 hours for the F-35A, and 11,000 hours for the F-35B. For comparison, observed MFHBME Unsch growth rates for several historical aircraft are shown in the table to the right.

Aircraft	MFHBME Growth Rate
F-15	0.14
F-16	0.14
F-22 (at 35,000 flight hours)	0.22
B-1	0.13
"Early" B-2 (at 5,000 flight hours)	0.24
"Late" B-2	0.13
C-17 (at 15,000 flight hours)	0.35

- These growth rates can still change, either increase or decrease, as the program introduces more reliability improvement initiatives and depending on how well they pan out in the field. Also, the Block 2B release expanded the aircraft's flight envelope and delivered initial combat capabilities. As a result, the fielded units will likely fly their aircraft more aggressively to the expanded envelope, and use mission systems more heavily than in the past. This change in operational use may uncover new failure modes that have an impact on sustaining or increasing reliability growth rates. Note that the above analysis covers a time span preceding Block 2B fleet release.
- The growth rates that the F-35 must achieve and sustain through 75,000 flight hours, in order to comply with ORD performance thresholds by maturity, have been demonstrated in the past, but mostly on bombers and transports. The F-22 achieved a MFHBME Unsch growth rate of 0.22, slightly less than the slowest growth rate the F-35 must sustain, for F-35A MFHBR, and only with an extensive and dedicated reliability improvement program.
- A number of components have demonstrated reliability much lower than predicted by engineering analysis. This drives down the overall system reliability and can lead to long wait-times for re-supply as the field demands more spare parts than the program planned to provide. Aircraft availability is also negatively affected by longer-than-predicted component repair times. The table below, grouped by components common to all variants, shows some of the high-driver components affecting low availability and reliability, followed by components failing more frequently on a particular variant or which are completely unique to it.

HIGH DRIVER COMPONENTS AFFECTING LOW AVAILABILITY AND RELIABILITY		
	Common to All Variants	Additional High Drivers by Variant
F-35A	• Avionics Processors • Nutplate and Engine Heat Blanket Cure Parameters • Low Observable Maintenance • Main Landing Gear Tires • Fuel System Components (Pumps and Valves)	• Exhaust Nozzle Converging-Diverging Link • Data Transfer Cartridge
F-35B		• Upper Lift Fan Door Actuator[1] • Flexible Linear Shaped Charge
F-35C		• Lightning Strike Damage • Nose Landing Gear Launch Bar Bolt[2]

1. Unique to the F-35B.
2. Unique to the F-35C.

Maintainability

- The amount of time needed to repair aircraft to return them to flying status remains higher than the requirement for the system when mature, but has improved over the past year. The program assesses this time with several measures, including Mean Corrective Maintenance Time for Critical Failure (MCMTCF) and Mean Time To Repair (MTTR) for all unscheduled maintenance. MCMTCF measures active

maintenance time to correct only the subset of failures that prevent the F-35 from being able to perform a specific mission, and indicates how long it takes, on average, for maintainers to return an aircraft to Mission Capable status. MTTR measures the average active maintenance time for all unscheduled maintenance actions, and is a general indicator of the ease and timeliness of repair. Both measures include active touch labor time and cure times for coatings, sealants, paints, etc., but do not include logistics delay times such as how long it takes to receive shipment of a replacement part.

- The tables below compare measured MCMTCF and MTTR values for the three-month period ending in May 2015 to the ORD threshold and the percentage of the value to the threshold for all three variants. The tables also show the value reported in the FY14 DOT&E Annual Report for reference. For all variants, the MCMTCF and MTTR times decreased (improved), with particularly strong decreases for the F-35A and F-35B MCMTCF. The F-35A improved to a much larger degree than either the F-35B or F-35C. Nonetheless, both maintainability measures for all variants were well above (worse than) the ORD threshold value required at maturity. Note that more current data than May 2015 are not available due to the Lockheed Martin database (FRACAS) not being compliant with all applicable DOD information assurance policies mandated by U.S. Cyber Command.

F-35 MAINTAINABILITY: MCMTCF (HOURS)				
Variant	ORD Threshold	Values as of May 31, 2015 (3 Mos. Rolling Window)	Observed Value as Percent of Threshold	Values as of August 2014 (3 Mos. Rolling Window)
F-35A	4.0	9.7	243%	15.6
F-35B	4.5	10.2	227%	15.2
F-35C	4.0	9.6	240%	11.2

F-35 MAINTAINABILITY: MTTR (HOURS)				
Variant	ORD Threshold	Values as of May 31, 2015 (3 Mos. Rolling Window)	Observed Value as Percent of Threshold	Values as of August 2014 (3 Mos. Rolling Window)
F-35A	2.5	4.9	196%	8.6
F-35B	3.0	7.1	237%	7.5
F-35C	2.5	5.8	232%	6.6

- More in-depth analysis between May 2014 and May 2015, in order to capture longer-term one-year trends, shows that MCMTCF and MTTR for all three variants are decreasing (improving), but with high month-to-month variability. For MCMTCF, the rate of decrease for the F-35A and F-35B is the highest, while improvements for the F-35C have been slower to manifest. For MTTR, the rate of improvement has been greatest for the F-35A, and slightly slower for the F-35B and F-35C.
- Several factors contribute to lengthy maintenance durations, especially adhesive cure times for structural purposes, such as attaching hardware (e.g., nutplates and installing heat blankets around the engine), as well as long material cure times for low observable repairs. From July 2014 to June 2015, program records show that maintenance on "attaching hardware," such as nutplates and heat blankets, absorbed approximately 20 percent of all unscheduled maintenance time, while low observable repairs accounted for 15 percent; these were the two highest drivers. The increased use of accelerated curing procedures, such as blowing hot air on structural adhesives or low observable repair pastes to force a quicker cure, may account for some of the decrease in repair times over the past year, but much room remains for improvement. The third highest driver of unscheduled maintenance, work on the ejection seat, by contrast, only accounted for 3 percent of all unscheduled maintenance hours.
- The immature state of the maintenance manuals and technical information maintainers use to fix aircraft may also negatively affect long repair times. The program is still in the process of writing and verifying Joint Technical Data (JTD) (see separate section in this report). Whenever maintainers discover a problem with no solution yet in JTD, and this problem prevents the aircraft from flying, the maintainers must submit a "Category I" Action Request (AR) to a joint government/Lockheed Martin team asking for tailored instructions to fix the discrepancy. This team can take anywhere from several days to nearly a month to provide a final response to each AR, depending on the severity and complexity of the issue. The number of final Category I AR responses per aircraft per month has been slowly increasing from December 2014 through August 2015. This trend indicates that, as the fleet matures, maintainers are continuing to face failure modes not adequately addressed by the JTD or that require new repair instructions. However, there are other reasons for submitting an AR, which may also partly account for this increasing trend. For example, depot teams submit ARs for depot-related repair work. More aircraft cycling through the modifications program, therefore, drives some of this increase. In addition, supply occasionally delivers parts with missing, incomplete, or incorrect electronic records, known as Electronic Equipment Logs (EELs), preventing those parts from being incorporated into the aircraft's overall record in Autonomic Logistics Information System (ALIS). In these cases, squadron maintenance personnel cannot electronically certify the aircraft safe for flight until supply delivers correct EELs, and maintenance personnel submit an AR to request these EELs.
- A learning curve effect is also likely improving repair times. As maintainers become more familiar with common failure modes, their ability to repair them more quickly improves over time.
- Maintainers must dedicate a significant portion of F-35 elapsed maintenance time to scheduled maintenance activities as well, which also affects aircraft availability

rates in addition to repair times. Scheduled maintenance accounted for 55 percent of all maintenance time from June 2014 to July 2015. (Scheduled maintenance time does not appear in either the MCMTCF or MTTR metrics.)
- Reducing the burden of scheduled maintenance by increasing the amount of time between planned in-depth and lengthy inspections that are more intrusive than routine daily inspections and servicing, will have a positive effect on how often aircraft are available to fly missions, provided experience from the field warrants such increases. An example is the engine borescope inspection, which were required after the engine failure on AF-27 in June 2014. The interval for these inspections increased after the program determined a fix to the cause of the failure and began implementing it on fielded aircraft. It will take more time and experience with field operations to collect data that show whether the program can increase inspection intervals without affecting aircraft safety for flight though.

Autonomic Logistics Information System (ALIS)
- The program develops and fields the ALIS in increments, similar to the method for fielding mission systems capability in the air vehicle. In 2015, the program fielded new versions of both hardware and software to meet requirements for the Marine Corps IOC. Although the program adjusted both schedule and incremental development build plans for ALIS hardware and software multiple times in 2014, it held the schedule more stable in 2015 by deferring capabilities to later software versions. The Program Office released several new versions of the software used in ALIS in 2015. However, each new version of software, while adding some new capability, failed to resolve all the deficiencies identified in earlier releases. Throughout 2015, formal testing of ALIS software has taken place at the Edwards AFB flight test center on non-operationally representative ALIS hardware, which relies on reach-back capability to the prime contractor at Fort Worth. The program still does not have a dedicated end-to-end developmental testing venue for ALIS, but has begun plans to develop one at Edwards AFB. This test venue, referred to as the Operationally Representative Environment (ORE), will operate in parallel with the ALIS squadron unit assigned to the operational test squadrons. The program plans to have the ORE in place as early as spring 2016. The ORE is planned to be a replicate of a full ALIS system and is needed to complete developmental testing of ALIS hardware and software in a closed environment to manage discoveries and corrections to deficiencies prior to OT&E and fielding to operational units. Meanwhile, formal testing, designated as Logistics Test and Evaluation (LT&E), remains limited and differs from how field units employ ALIS. For example, the flight test center at Edwards AFB does not use Prognostic Health Management (PHM), Squadron Health Management (SHM), Anomaly and Failure Resolution System (AFRS), and the Computerized Maintenance Management System (CMMS), each of which are modules within ALIS that the operational units use routinely.

ALIS Software Testing and Fielding in 2015
- During 2015, the program accomplished the following with ALIS software:
  - The program transitioned all fielded units from ALIS 1.0.3 to 2.0.0 between January and April 2015. This software includes integrated exceedance management, improved interfaces with legacy government systems, an upgrade to Microsoft Windows 7 on laptop and other portable devices, fixes to deficiencies, and reduced screen refresh and download times. Testing of software 2.0.0 identified two Category 1 deficiencies (same categorization as previously explained in this report in "Mission Systems" section), both of which remained uncorrected when the program delivered the software to field units. According to the program's LT&E report on ALIS 2.0.0, the test team identified the following deficiencies:
    - A deficiency in the air vehicle's maintenance vehicle interface (MVI)—the hardware used to upload aircraft data files—corrupted the aircraft software files during the upload process. Technical manuals in ALIS direct the process for loading aircraft files. The contractor addressed this deficiency by creating a fix in the final Block 2B aircraft software, and the program fielded it in 2015.
    - The Mission Capability Override (MCO) feature gives maintenance supervisors the authority and ability to override an erroneous mission capability status in ALIS. The LT&E of ALIS 1.0.3, conducted in September and October 2012, revealed a discrepancy in the mission capability status between two modules of ALIS. The Computerized Maintenance Management System (CMMS), which uses Health Reporting Codes (HRCs) downloaded from the aircraft, can report an aircraft as Mission Capable. Meanwhile, another module within ALIS, the Squadron Health Management (SHM), which makes the mission capable determination based on the Mission Essential Function List, could categorize the aircraft as Non-Mission Capable (NMC). This discrepancy is a result of errors in the interfaces between HRCs and the list of mission essential functions. When this discrepancy occurs, maintenance supervisors should be able to use the MCO feature to override either status within ALIS, which makes the aircraft available for flight. However, the Mission Capability Override is deficient because it does not allow override of the status within SHM (the override functions properly for CMMS). In ALIS 2.0.0, the same deficiency remains. However, ALIS 2.0.0 adds capabilities using the aircraft status in SHM to collect the mission capable status of aircraft across the fleet. Using SHM status to generate fleet availability metrics may be inaccurate because of the MCO deficiency.

- In addition to the Category 1 deficiencies listed above, the LT&E test team also identified 56 Category 2 deficiencies (same categorization as previously explained in this report in "Mission Systems" section) in the ALIS 2.0.0 report. The following list highlights deficiencies, either singly or in related groups, which affect aircraft maintenance and sortie generation rates:
  - » Parts management functionality within CMMS, which alerts ALIS users if maintainers attempt to install an incorrect part on an aircraft after the aircraft has undergone modification (i.e., modifications needed due to concurrency of development with production), is deficient. Once an aircraft has undergone modification, maintainers should install only specific, newer types and models of parts. However, CMMS incorrectly authorizes older/inappropriate replacement parts, changing the aircraft to an unauthorized configuration, which lacks the attributes of the modification. The configuration management function of CMMS is also deficient, as it does not maintain accurate configuration records of aircraft with completed modifications when CMMS has permitted the installation of infidel parts on the aircraft.
  - » Maintainers must use manual workarounds to ensure the aircraft mission capable status is accurate if they determine additional maintenance is required beyond that dictated by the HRCs from the post-mission download. For example, if maintenance personnel find or cause additional problems while performing maintenance, they must create new work orders with appropriate severity codes indicating that an aircraft is no longer mission capable. However, CMMS and SHM will not reflect that new aircraft status, requiring a maintenance supervisor to open each work order to review the actual, current aircraft status.
  - » The heavy maintenance workload, required to enter pertinent maintenance data into ALIS, causes field units to create workarounds, including creating task templates outside of ALIS to get maintenance records into ALIS.
  - » AFRS, designed to provide a library of possible maintenance actions for each HRC does not have the troubleshooting solutions for approximately 45 percent of the HRCs.
  - » Data products that ALIS is dependent on to make mission capable determinations, such as HRCs, the HRC nuisance filter list, AFRS troubleshooting libraries, and the mission essential function list, do not sufficiently manage configuration by including version, release date, applicability, or record of changes. As a result, maintenance personnel spend additional time correlating the data files to the individual aircraft—a process which increases the risks of errors and loss of configuration management of the aircraft assigned to the units.
  - » Long wait times to synchronize the Portable Maintenance Aid to transfer work order data to the ALIS squadron unit.
  - » Long wait times needed to complete data searches, export reports, and apply processes within ALIS.
- The program developed ALIS 2.0.1 to upgrade to Windows Server 12, add new capabilities required to support the Marine Corps' IOC declaration in mid-2015, and address ALIS 2.0.0 deficiencies. The program completed the LT&E of ALIS 2.0.1 in May 2015, but results were poor, so the program did not release the software to the field. As of the writing of this report, the program had not signed out the ALIS 2.0.1 LT&E report. According to their "quick look" briefing, the test team discovered five new Category 1 deficiencies and confirmed that the contractor did not correct in ALIS 2.0.1 the two Category 1 deficiencies identified during ALIS 2.0.0 testing (listed above). According to the briefing, the five new Category 1 deficiencies are:
  - The Integrated Exceedance Management System, designed to assess and report whether the aircraft exceeded limitations during flight, failed to function properly. The Services require proper functioning of this capability to support post-flight maintenance/inspections and safe turnaround for subsequent flights.
  - AFRS, which is critical to troubleshooting and maintenance repairs, demonstrated unstable behavior and frequently failed because of interface problems and a system licensing configuration issue.
  - ALIS randomly prevented user logins.
  - The maintenance action severity code functionality in CMMS—designed to automatically assign severity codes to work orders as maintenance personnel create them—did not work correctly.
  - ALIS failed to process HRCs correctly when maintenance personnel used CD media to input them into ALIS at sites that do not use PMD readers (described below) to download maintenance data.
- The program developed another version of ALIS, version 2.0.1.1, which contained numerous software "patches" designed to correct the five Category 1 deficiencies discovered by the test team during the LT&E of ALIS 2.0.1. The test team conducted an LT&E in May and June 2015 specifically to determine if Lockheed Martin had resolved each deficiency. The test team evaluated the correction for each deficiency as the contractor delivered the software patches. As of the end of November, the program had not signed out the LT&E report on ALIS 2.0.1.1, but according to the test team's "quick look" briefing, they recommended releasing ALIS 2.0.1.1 to the fielded units, which the program completed between July and October 2015. In their "quick look" briefing, the test team also noted failures of redundant systems and workarounds that were required to address other unresolved problems. These included:

    - Frequent failures of the aircraft memory device, which serves as a back up to the PMD, to download into ALIS when the PMD is corrupted.
    - CMMS and SHM exhibited disparities in tracking on-aircraft equipment usage which required maintainers to develop and operate a parallel tracking system independent of ALIS.
    - Managing data loads associated with mission planning required extensive contractor support as the maintenance-vehicle interface did not support direct loading to the aircraft as designed.
    - Air vehicle data transfer between squadron hardware, required for deployments and aircraft induction to and from depots, required extensive contractor support.
    - Air vehicle lockdown capability, needed for impounding an aircraft in the event of an investigation, did not work.
  - All versions of ALIS have demonstrated persistent problems with data quality and integrity, particularly in the Electronic Equipment Logbooks (EELs), which allow usage tracking of aircraft parts. Frequently, EELs are not generated correctly or do not transfer accurately, requiring manual workarounds that extend aircraft repair and maintenance times. Without accurate EELs data, ALIS can improperly ground an aircraft or permit an aircraft to fly when it should not.

ALIS Hardware Fielding in 2015

- During CY15, the program demonstrated progress in the development and fielding of ALIS hardware and aligning hardware versions with the software versions noted above.
  - The program delivered the first deployable version of the Squadron Operating Unit (SOU), deemed SOU V2 (Increment 1), aligned with ALIS software 2.0.1, to MCAS Yuma to support Marine Corps IOC. The originally fielded unit-level hardware, SOU V1, failed to meet ORD deployability requirements due to its size and weight. SOU V2 incorporates modular components that meet two-man-carry transportation requirements and decrease set-up time. Additionally, field units can tailor the SOU V2 by adjusting the number of components with which they deploy depending on projected duration. SOU V2 allowed the program to meet requirements for Marine Cops IOC. It will support Block 2B, 3i, and 3F aircraft. The program plans to field one set of SOU V2 hardware for each F-35 unit and an additional set of SOU hardware for each F-35 operating location. During partial squadron deployments, the unit will deploy with their SOU V2 while the remainder of the squadron's aircraft will transfer to the base-level SOU.
  - Because the Edwards AFB flight test center does not have an SOU V2, the program conducted the hardware portion of the LT&E at Fort Worth in May 2015. Testing included demonstrating that PMDs from aircraft at the flight test center downloaded correctly into the SOU V2.
  - The program continued to field PMD readers to operating locations. As designed, maintainers download aircraft PMDs post flight to ALIS through a Ground Data Security Assembly Receptacle (GDR). However, it takes between 1.0 and 1.2 hours to download all data from a 1-hour flight. PMD readers download maintenance data only within 5 minutes, permitting faster servicing of aircraft.
  - The program delivered an SOU V2 to the JOTT at Edwards AFB in November 2015. This SOU V2 will be "on loan" from Hill AFB, Utah, and is planned to be used in an F-35A deployment to Mountain Home AFB, Idaho, in March 2016 with six Air Force F-35A aircraft.
  - Lockheed Martin delivered full SOU V2 kits to MCAS Yuma in May 2015 and to the Pilot Training Center at Luke AFB, Arizona (for Norway) in October. Because Israel did not require an SOU V2 when scheduled for delivery, the Program Office arranged for it to go to MCAS Yuma in November 2015, so the squadron could use it in an assessment of the F-35B's capabilities at an austere location. The program delivered an SOU V2 deployment kit to Nellis AFB and a Central Point of Entry (CPE) kit, which included a CPE and an SOU V1, for United Kingdom lab use, in December 2015. A full SOU kit includes more peripheral equipment than a deployment kit.

Cross Ramp Deployment Demonstration May 2015

- During April and May 2015, the Air Force's Air Combat Command tasked the 31st Test and Evaluation Squadron (TES) at Edwards AFB to conduct a limited deployment of F-35A aircraft as part of the de-scoped Block 2B operational test activity. This deployment, from one hangar on the flight line at Edwards AFB to another hangar, termed the Cross Ramp Deployment Demonstration (CRDD), gave the program and the Air Force an opportunity to learn how to deploy the F-35 air system and ALIS. Originally, the 31st TES planned to use ALIS 2.0.1, but delays in releasing that software resulted in the need to use ALIS 2.0.0 instead. Overall, the CRDD showed that ALIS 2.0.0 deficiencies, plus difficulties encountered during the CRDD in downloading and transferring data files from home station to a deployed location, will negatively affect sortie generation rate if they remain uncorrected. The CRDD also demonstrated that getting ALIS 2.0.0 online with current maintenance information while also conducting flying operations is time consuming, complex, and labor intensive. Working around ALIS 2.0.0 deficiencies in this manner was possible for this demonstration of limited duration; however, it would not be acceptable for deployed combat operations.
  - The 31st TES deployed across the ramp on the flightline by packing and moving an ALIS SOU V1 loaded with ALIS 2.0.0 software, mission planning hardware, maintenance personnel, support equipment, and tools. Three F-35A aircraft "deployed" to the cross ramp location after the ALIS SOU V1 was in place. For supply support, maintenance personnel obtained spare parts from the base warehouse as though they had not deployed (i.e., the 31st TES did not deploy in this demonstration with a

pre-planned set of spares as an operational unit would have for an actual deployment).

- Transfer of aircraft data from the SOU at the main operating location to the SOU at the "deployed" location and getting the SOU online took several days to complete and required extensive support from Lockheed Martin ALIS administrators, a level of effort not planned for the deployment and not operationally suitable. Although not finalized by the Services, deployment concepts of operation will include procedures for transferring aircraft data between SOUs via secure electronic methods. The test team attempted the primary electronic method, but the configuration of the deployed SOU caused it to fail. Ultimately, data transfer occurred using the physical transfer of back-up CDs to the deployed location, but the 31st TES could not load the files until the end of the third of the five days of flight operations, because administrators had to load multiple software patches, and resolve ALIS account problems for every authorized user. After loading the aircraft data on the deployed SOU, administrators also had to enter manually all maintenance performed on the aircraft during this time into the SOU before bringing ALIS online to support operations.
- Flight operations did take place without the support of normal ALIS operations for the three days while the test team worked to get the SOU online. During this period, maintenance personnel prepared and recovered aircraft without a full post-mission download of maintenance data, including health and fault codes normally captured and transmitted to ALIS 2.0.0. The deployed aircraft generally required only routine maintenance such as tire changes, which maintainers could complete without access to all maintenance instructions. One aircraft experienced a radio failure, which did not require an HRC download to diagnose, and did not fly again until maintainers replaced the radio.
- To prepare for the deployment, the 31st TES did not fly the aircraft designated for the deployment during the week prior, allowing maintenance personnel to prepare the aircraft and ensure all inspections were current and maintenance actions complete. This preparation allowed the unit to conduct flight operations for three days during the deployment while the SOU remained offline.
- At the end of the demonstration, the 31st TES successfully transferred data to the Autonomic Logistics Operating Unit at Fort Worth—per one of the electronic methods of transfer expected for deployed operations—but staffing levels at Lockheed Martin were insufficient to complete the transfer all the way back to the home station SOU. Instead, the 31st TES transferred data back to the home station SOU via an alternative, web-based, secure, online file transfer service operated by the Army Missile Research and Development Center, referred to as "AMRDEC."
- The CRDD showed that although cumbersome, field units could relocate the SOU V1 hardware to a deployed operating location and eventually support operations with that hardware. However, difficulties in transferring data between home station and a deployed SOU made the deployment and redeployment processes time consuming and required extensive support from the contractor to complete. Although ALIS 2.0.1.1 added improvements to data transfer capabilities, the program has not yet demonstrated those improvements in a Service-led deployment exercise. Therefore, it is unknown the extent to which ALIS 2.0.1.1 improves data transfer capabilities.

Marine Corps Austere Assessment Deployment Demonstration, December 2015

- The Marine Corps deployed eight production F-35B aircraft—six from VMFA-121 at Marine Corps Air Station (MCAS) Yuma, Arizona, and two from VMX-22 at Edwards AFB, California—to the Strategic Expeditionary Landing Field (SELF) near MCAS Twentynine Palms, California, from December 8 – 15, 2015, to assess deployed operations to an austere, forward-base location. The Marine Corps aligned the deployment with a combined arms live fire exercise, Exercise Steel Knight, to have the F-35 detachment provide close air support for the rest of the exercise participants as the forward deployed air combat element (ACE). The SELF had an airfield constructed of AM2 matting (aluminum paneling engineered for rapid runway construction to support austere operations) and minimal support infrastructure, which required the Marine Corps to deploy the necessary support equipment, spare parts, and personnel; and set up secure facilities on the flightline to conduct F-35B flight operations. Although it was not a formal operational test event, the JOTT and DOT&E staff observed operations and collected data to support the assessment.
  - While deployed, and in support of the exercise, the Marine Corps flew approximately 46 percent of the planned sorties (28 sorties flown versus 61 sorties planned), not including the deployment, redeployment, and local familiarization sorties. Accounting for all sorties (i.e., deploying and redeploying, local training, aircraft diverts and swapping one aircraft at home station) the Marine Corps flew approximately 54 percent of scheduled sorties (82 scheduled versus 44 flown). Weather, particularly high winds, aircraft availability, and problems transferring aircraft data from the home station to the deployed ALIS SOU all contributed to the loss of scheduled sorties.
  - The Marine Corps planned to employ inert GBU-12 and GBU-32 weapons in the CAS role during the exercise. The Marine Corps ordnance loading teams completed multiple GBU-12 and GBU-32 upload and download evolutions at the SELF. However, pilots released fewer weapons than planned due to weather and range limitations.
  - Two aircraft experienced foreign object damage to their engines from debris ingested during operations, grounding them until the end of the deployment. The engine damage on both aircraft was not severe enough to cause an engine

change, but required a Pratt and Whitney technician, certified in blending out damage to engine blades, to repair the engines on both aircraft at Twentynine Palms so they could return to flyable status, allowing the aircraft to return to home station at the end of the deployment. No further action was required for the engine repairs on either aircraft. It was still unknown at the time of this report how these types of engine repairs would be conducted during deployed or combat operations.
- The deployment was the first to use the ALIS Standard Operating Unit Version 2 (SOU V2), which is smaller, lighter weight and more modularized than Version 1. Although Marine Corps ALIS personnel were able to set up the SOU V2 (i.e., place and connect the modules and apply power) within a few hours after arrival, setting up connectivity with the broader Autonomic Logistics Global Support (ALGS) function did not occur for quite some time. The Customer Relations Module (CRM) of ALIS, used to submit action requests to the contractor for resolving maintenance actions, operated only intermittently during the deployment.
- The transfer of data from home station to the deployed ALIS SOU took several days to fully complete, a process that is not affected by the version of SOU being used. Since the SOU V2 lacked connectivity to the Autonomic Logistics Operating Unit, which is required for transferring data via the preferred method of keeping the data entirely within the infrastructure of ALIS, initial data transfers for the six aircraft from MCAS Yuma were AMRDEC. Files were transferred to workstations at the deployed site and then loaded into ALIS via CDs. The downloading of files from AMRDEC was slowed several times when SATCOM connectivity was lost during the process. The aircraft from Edwards AFB, however, brought CD's with them for transfer into ALIS.
- The deployment provided valuable "lessons learned" for the Marine Corps as it develops concepts of operation for forward basing and austere operations. While the SOU V2 proved to be easier and quicker to set up than the SOU V1, transferring aircraft data from home station to the deployed location continued to be problematic. Poor aircraft availability reduced the support the F-35B ACE was able to provide to the large force exercise.

ALIS Software and Hardware Development Planning through the End of SDD

- In CY15, the program continued to struggle with providing the planned increments of capability to support the scheduled releases of ALIS software 2.0.x and 3.0.x. The program approved changes to the content of the ALIS developmental software release plan in April 2015 for ALIS 2.0.1 and 2.0.2. To adhere to the previously approved software release schedule for ALIS 2.0.1, the program deferred several capabilities, including cross-domain solutions for information exchange requirements and firewall protections for low observable and mission planning data, to a later fix release. The Marine Corps, which required ALIS 2.0.1 for IOC, supported the Program Office's plan to defer these capabilities until after IOC.
  - These deferrals are in addition to decisions in 2014 to defer life-limited parts management capabilities to ALIS 2.0.2 and ALIS 3.0.0.
  - Although the re-plan included a two-month delay in the LT&E dates for ALIS 2.0.1 from March to May 2015, the program did not change the initial fielding date of July 2015, the planned date for Marine Corps IOC. The program also approved a fix release of this software to follow almost immediately.
  - The program had previously scheduled fielding of software 2.0.2, beginning in December 2015, but approved a nearly eight-month delay to late July 2016. The Air Force IOC requirement is for ALIS software 2.0.2 to be fielded. Since the Air Force also requires operationally representative hardware and software 90 days before declaring IOC, the delayed schedule does not support the Air Force IOC objective date of August 2016. An additional potential problem is that the program currently does not plan to conduct cybersecurity penetration testing during the development of this ALIS release or any future developmental releases, but will instead rely on previous, albeit limited, cybersecurity test results. This decision increases the risk that the program will not be aware of ALIS vulnerabilities before making fielding decisions. However, the JOTT will complete operational cybersecurity testing of fielded ALIS components.
  - At an April 2015 review, the program projected initial fielding of ALIS 3.0.0 in June 2017 and indicated they would propose combining ALIS 3.0.0 and 3.0.1 (previously planned for December 2017) into a single release in June 2018. Should this occur, ALIS software will not include full life limited parts management, a capability planned for Marine Corps IOC, until nearly three years after Marine Corps IOC. All fielded locations will require high levels of contractor support until the program integrates life limited parts management capability into ALIS. In November 2015, the program proposed changing the content of ALIS 3.0.0 to reflect service and partner priorities and moving the fielding date forward by approximately six months.
  - The program has deferred the PHM downlink originally planned for release in ALIS 2.0.0 indefinitely because of security concerns.
- The program plans the following hardware releases to align with software releases noted above:
  - The program plans SOU V2 (Increment 2) to align with ALIS 2.0.2 and include additional SOU V2 hardware improvements to support Air Force IOC, including dynamic routing to deliver data via alternate network paths and sub-squadron reporting to allow deployed assets to report back to a parent SOU.

- The third increment of SOU V2 hardware will address Service requirements for decentralized maintenance, allowing personnel to manage maintenance tasks whether or not they connect their portable maintenance aid (PMA) to the main SOU (the PMA provides connectivity between maintenance personnel and the aircraft, enabling them to do maintenance tasks on the aircraft by viewing technical data and managing work orders downloaded from the SOU). Increment 3 will also permit units to conduct deployments without SOU hardware, instead relying on PMAs. This increment of SOU V2 will align with ALIS release 3.0.0.

Prognostic Health Management (PHM) within ALIS

- The PHM system collects air system performance data to determine the operational status of the air vehicle and, upon reaching maturity, will use data collected across the F-35 enterprise and stored within PHM to predict maintenance requirements based on trends. The PHM system provides the capability to diagnose and isolate failures, track and trend the health and life of components, and enable autonomic logistics using air vehicle HRCs collected during flight and saved on aircraft PMDs. The F-35 PHM system has three major components: fault and failure management (diagnostic capability), life and usage management (prognostic capability), and data management. PHM diagnostic and data management capabilities remain immature. The program does not plan to integrate prognostic capabilities until ALIS 2.0.2.
  - Diagnostic capability should detect true faults within the air vehicle and accurately isolate those faults to a line-replaceable component. However, to date, F-35 diagnostic capabilities continue to demonstrate poor accuracy, low detection rates, and a high false alarm rate. Although coverage of the fault detection has grown as the program has fielded each block of F-35 capability, all metrics of performance remain well below threshold requirements. The table below compares specific diagnostic measures from the ORD with current values of performance through June 2015.
  - PHM affects nearly every on- and off-board system on the F-35. It must be highly integrated to function as intended and requires continuous improvements for the system to mature.
- Poor diagnostic performance increases maintenance downtime. Maintainers often conduct built-in tests to see if the fault codes detected by the diagnostics are true faults. False failures (diagnostics detecting a failure when one does not exist) require service personnel to conduct unnecessary maintenance actions and often rely on contractor support to diagnose system faults more accurately. These actions increase maintenance man-hours per flight hour, which in turn can reduce aircraft availability rates and sortie generation rates. Poor accuracy of diagnostic tools can also lead to desensitizing maintenance personnel to actual faults.

METRICS OF DIAGNOSTIC CAPABILITY
(6-month rolling window as of June 2015. Data provided by the Program Office are considered "preliminary" as they have not completed the formal adjudication process by the data review board.)

Diagnostic Measure	Threshold Requirement	Demonstrated Performance		
		Block 1	Block 2	Block 3
Developmental Test and Production Aircraft				
Fault Detection Coverage (percent mission critical failures detectable by PHM)	N/A	65	73	84
Fault Detection Rate (percent correct detections for detectable failures)	98	65	73	85
Fault Isolation Rate (percentage): Electronic Fault to One Line Replaceable Component (LRC)	90	68	69	72
Fault Isolation Rate (percentage): Non-Electronic Fault to One LRC	70	76	72	79
Fault Isolate Rate (percentage): None-Electronic Fault to 3 or Fewer LRC	90	82	87	87
Production Aircraft Only				
Mean Flight Hours Between False Alarms	50	0.20	0.60	0.18
Mean Flight Hours Between Flight Safety Critical False Alarms	450	1,360	543	170
Accumulated Flight Hours for Measures	N/A	1,360	4,886	1,360
Ratio of False Alarms to Valid Maintenance Events	N/A	44:1	16:1	1079:1

  - Qualified maintenance supervisors can cancel an HRC without generating a work order for maintenance actions if they know that the HRC corresponds to a false alarm not yet added to the nuisance filter list. In this case, the canceled HRC will not result in the generation of a work order, and it will not count as a false alarm in the metrics in the above table. The program does not score an HRC as a false alarm unless a maintainer signs off a work order indicating that the problem described by the HRC did not occur. Because PHM is immature and this saves time, it occurs regularly at field locations but artificially lowers the true false alarms rate (i.e., actual rate is higher).
  - Comparing the values in the table above with previous reports, Mean Flight Hours Between Flight Safety Critical False Alarms is the only diagnostic metric that has shown significant improvement over the last year. Other metrics have stayed either flat or decreased (worsened) slightly.

- The following lists the systems most likely to result in missed fault detections, incorrect fault isolations, and false alarms as of June 2015:
  - Missed detections. Integrated Core Processor, power and thermal management system, panoramic color display, communications-navigation-identification (CNI) rack modules, and the Helmet Mounted Display System.
  - Incorrect isolation. Integrated Core Processor, power and thermal management system, electronic warfare, fuel system, CNI rack modules, and hydraulic power system.
  - False alarms. CNI system, propulsion, electronic warfare, suspension and release, displays and indicators in general.

Off-board Mission Support (OMS) within ALIS

- OMS provides F-35 ground mission planning, mission debrief, security, and sensor management capabilities. Similar to other components of ALIS, the program does not have a developmental test venue for OMS. Mission planning modules include the baseline Joint Mission Planning System software that pilots and tacticians use to develop files for uploading into the aircraft prior to flight. OMS includes separate hardware such as workstations and encryption/decryption devices and networks with ALIS for data management. In addition to mission planning, OMS provides the following functions:
  - Ground security that allows for secure data management and cryptologic key management at multiple classification levels
  - Sensor management and selection of mission data files to create a mission data load
  - Mission debrief capability for replaying audio and video from completed flights
- Until September 2015, the training center did not provide hands-on training on OMS, requiring the pilots to learn it through trial and error and by asking questions of the contractor. Also, the program has not yet provided OMS user manuals. As a result, field units will likely have difficulty providing the expertise to create tailored, theater-specific mission data loads during contingency operations. Few pilots currently possess the training and experience to build mission data loads from beginning to end.
- OMS deficiencies will have a negative impact on combat mission and training flight operational tempo. Long processing times create bottlenecks in both mission planning and mission debrief, particularly for multi-ship missions.
  - Pilots transfer a mission plan into the PMD using a GDR, which encrypts the information. The PMD loading process is unnecessarily complex, taking 25 to 45 minutes to transfer a mission data load from an OMS workstation to a PMD. If pilots transfer the same mission data load to multiple PMDs for a multi-ship mission, each PMD is encrypted separately with no time savings.
  - OMS requires excessive time for loading of PMDs and decryption of mission data and does not support timely mission debrief, particularly if pilots fly multiple missions in one day. For example, a 1-hour mission typically takes between 1.0 and 1.2 hours to decrypt, and depending on the amount of cockpit video recorded, can take longer.
  - Administrative functions in OMS, such as theater data load updates, user authentication file updates, cryptographic updates, and data transfers are inefficient and require excessive times to complete.
    - Because of cryptographic key expirations, OMS administrators must update the theater data load at least every 28 days. The OMS administrator builds the load on OMS equipment, transfers it to a separate laptop, creates a CD, and then uploads it to the SOU. Again, personnel cannot build cryptographic key loads on one OMS workstation and export it to others in the same unit; they must build them individually.
    - Personnel must install cryptographic keys on the aircraft, OMS workstations, GDRs, and GDR maintenance laptops.
    - Block 2B aircraft have 33 different cryptographic keys with varying expiration periods. When building a key for the entire jet, an error frequently means rebuilding from the beginning, which can take several hours.
    - The cryptographic key management tool is not intuitive, prone to errors, and does not have a validation function so the user can determine if a key load is accurate prior to transferring it to the aircraft.
    - Loading of incorrect keys can result in aircrew not having capabilities such as secure voice transmissions.
    - Local security policies vary, making hardware requirements and information technology processes different at each operating location.
  - Current OMS hardware does not have the necessary video processing and display capabilities to allow pilots to effectively debrief a multi-ship mission. Current debriefing capability via laptops does not provide adequate resolution or a large enough presentation for a four-ship debrief.

Joint Technical Data (JTD)

- Although the verification of Joint Technical Data (JTD) modules has proceeded through 2015, field units continue to face challenges where JTD is either not yet verified, is unclear, or includes errors. To work around these challenges, personnel must frequently submit ARs to the contractor and wait for the engineering disposition, a process that adds to maintenance time.
- The program identifies JTD modules and the primary contractors develop and verify them in the field. Once JTD modules complete verification, the program includes them in the JTD package distributed periodically to all field locations through ALIS. At the field locations, they are downloaded to unit-level SOUs and PMAs. JTD updates currently require

downloading of the entire JTD package (i.e., partial changes to JTD cannot be distributed to fielded units).
- ALIS release 2.0.0 included Trilogi Viewer 4.0, which supports delivery of partial builds and amendments to JTD to reduce the time required to install JTD updates at the unit level. However, the program determined that this version of Trilogi contains a software error, which prevented implementation of this capability until corrected. As of December 2015, the program continues to distribute only complete, bundled JTD packages.
- The total number of identified data modules grows each year as the program matures and low-rate initial production (LRIP) contracts include additional JTD delivery requirements. The air-vehicle JTD includes time compliance technical data, depot-level technical data, air vehicle diagnostics and troubleshooting procedures, complete structural field repair series data, aircraft battle damage assessment and repair, and maintenance training equipment. According to the most recent data from the Program Office, as of September 2015, propulsion JTD development is nearly complete and on schedule. To support Marine Corps IOC, the contractor focused on development of F-35B unit-level and Supportable Low Observable (SLO) JTD and deferred approximately 260 data modules, identified by the Marine Corps as not needed until after IOC, such as JTD modules for loading weapons not yet cleared for use.
- Although the program included development of support equipment JTD in the SDD contract, the program funded additional support equipment via another, separate contract, which requires approximately 1,700 more data modules. The contract began in July 2014 and the modules must be verified before the end of SDD.
- The program estimates that development of all JTD for each variant of the air vehicle and for propulsion will meet Service milestones.
- DOT&E sees risk in the ability of the program to complete air vehicle JTD verifications in time to meet Service needs. The program does not have a formal JTD verification schedule nor dedicated time to complete air vehicle JTD verifications. In addition, it depends on the availability of aircraft, primarily at Edwards and Eglin AFBs, to complete this work. JTD verifications have lower priority than maintaining the flight schedule, so verification teams normally cannot schedule dedicated events.
  - The program did focus on completing F-35B unit-level verifications during 2015 with verifications lagging development by fewer than 200 modules out of 5,157 developed.
  - The program will not complete highly invasive JTD verifications, such as those for removing fuel cells, until an aircraft requires this level of maintenance.
  - The program did not fund SLO JTD verifications until March 2014, so SLO JTD lags other verification efforts. However, most SLO JTD verification will take place using desktop analysis, and the program expects verification for all variants to proceed on schedule.
- As of September 2015, the program had verified approximately 94 percent of the identified air vehicle JTD modules for the F-35A, 93 percent of the F-35B, and 73 percent of the F-35C. The table below shows the number of JTD modules identified, developed, and verified for the air vehicle by variant, pilot flight equipment, support equipment, and SLO. Overall, approximately 77 percent of these modules have been identified, developed, and verified. The program tracks propulsion JTD separately.

F-35 SDD JOINT TECHNICAL DATA (JTD) DEVELOPMENT AND VERIFICATION STATUS REQUIRED BY COMPLETION OF SYSTEM DEVEOLOPMENT AND DEMONSTRATION (SDD) CONTRACT
Air Vehicle, Pilot Flight Equipment (PFE), Support Equipment (SE), and Supportable Low Observable (SLO) (as of end of September 2015)

	Module Type	Modules Identified	Modules Developed	Percent Identified Modules Developed	Number of Verification Events[1]	Percent Identified Modules Verified
F-35A[2]	Unit-level	4,603	4,326	94 %	4,328	Not Determined
F-35B[2]	Unit-level	5,335	5,157	97 %	4,966	93 %
F-35C[2]	Unit-level	4,766	4,009	84 %	3,488	73 %
Common (all variants)[3]	Unit-level	84	58	69 %	62	Not Determined
PFE	Common	326	318	98 %	274	84 %
SE	Common	2,345	1,596	68 %	1,351	58 %
SLO	F-35A	745	599	79 %	80	11 %
	F-35B	739	739	100 %	428	58 %
	F-35C	668	97	15 %	79	12 %
	Common	6	6	100 %	4	67 %
TOTAL		19,617	16,905	86 %	15,060	77 %

1. For F-35A and Common modules, multiple verifications are required for some single data modules, hence values represent verifications and exceed the number of modules developed.
2. Includes field- and depot-level JTD for operations and maintenance, on- and off-equipment JTD, and structured field repairs.
3. Includes aircraft JTD for general repairs, sealants, bonding, structured field repairs, and non-destructive investigations.

Air-Ship Integration and Ship Suitability Testing
F-35B

- The Marine Corps conducted a suitability demonstration with six operational (i.e., non-test fleet) F-35B aircraft onboard the USS *Wasp* from May 18 – 29, 2015.
  - Despite bearing the title "OT-1" for "Operational Test – One," as expected, the demonstration was not

an operational test and could not demonstrate that the F-35B is operationally effective or suitable for use in any type of limited combat situation. This was due to many factors concerning how the demonstration was structured including, but not limited to, the following major features that were not operationally representative:

- Other aircraft of a standard Air Combat Element (ACE)—with which the F-35B would normally deploy—were not present, except for the required search and rescue helicopters, granting the F-35B unit practically sole use of the flight deck and hangar bay.
- The embarked F-35B aircraft lacked the full complement of electronic mission systems necessary for combat, and not all the normal maintenance procedures necessary to keep those systems in combat-capable state of readiness were exercised.
- The aircraft did not have the appropriate flight clearances to carry or employ any ordnance. Ordnance evolutions were limited to maintainers uploading and downloading inert bombs and missiles on the flight deck.
- Uniformed maintainers had not yet been equipped with complete maintenance manuals and mature troubleshooting capabilities, necessitating the extensive use of contractor maintenance personnel that would not be present on a combat deployment.
- Production-representative support equipment was not available. Instead, the demonstration used interim support equipment cleared for hangar bay use only and requiring workarounds for conducting maintenance, such as fueling operations, on the flight deck.
- The operational logistics support system, known as the Autonomic Logistics Global Sustainment system, was not available. A potentially non-representative set of spare parts was loaded onboard the ship, and the program and Marine Corps provided extensive supply support to ensure replacement parts reached the ship faster than would be expected in deployed combat operations.

- The USS *Wasp* demonstration event did, however, provide useful training for the Marine Corps and amphibious Navy with regards to F-35B operations onboard L-class ships, and also provided findings relevant to the eventual integration of the F-35B into the shipboard environment.
- The Marine Corps and Lockheed Martin could not transfer data for the aircraft, support equipment, spare parts, and personnel from ashore sites to the SOU onboard the ship entirely within the ALIS network as originally envisioned, due to the immaturity of the Autonomic Logistics Operating Unit. An attempt was made to download the data onto the ship via other government and contractor networks, but the download rate over the ship's network proved too slow to efficiently move the numerous large files. Finally, the data were downloaded off-ship via commercial Wi-Fi access, burned to CDs, and imported directly onto the *Wasp*'s SOU. This method of transferring data would not be acceptable for routine combat deployments.
  - Similarly, once the USS *Wasp* was underway, service personnel noted that getting ALIS-related data to the ship to support flight operations, such as the EEL records for spare parts delivered by supply, was slow over satellite communications channels.
  - In addition to the difficulties moving the data back and forth between the *Wasp* SOU and ashore site SOUs, data discrepancies were introduced during the transfer process, including inconsistencies and lost data. Transfer of aircraft data from the shore-based SOU to the *Wasp* SOU took nearly two days to complete, and maintenance personnel were correcting discrepancies found in the aircraft data in ALIS for four additional days. For example, when the aircraft data files were finally received onboard the USS *Wasp*, all outstanding parts requisitions for the aircraft had been stripped. The transfer of support equipment data took 10 days to complete and maintenance personnel were correcting deficiencies in the data during the majority of the at-sea period.
- Aircraft reliability and maintainability were poor enough that it was difficult for the Marines to keep more than two to three of the six embarked aircraft in a flyable status on any given day, even with significant contractor assistance. Aircraft availability during the deployment was approximately 55 percent. Around 80 percent availability would be necessary to generate four-ship combat operations consistently with a standard six-ship F-35B detachment.
- Aircraft availability varied significantly from aircraft to aircraft, however, with some aircraft requiring no major maintenance, and other aircraft barely contributing to meaningful flight operations. In particular, one aircraft, designation BF-23, was reported "Full Mission Capable (FMC)" for the entire 11-day duration of the deployment. Another aircraft, BF-37, flew less than 5 hours, including diverting to shore and back for a landing gear malfunction, and was not flyable for 8 of the 11 days. BF-37 was notable for being in depot modification from December 8, 2014, to May 8, 2015, right before the start of the demonstration. Fleet units have reported initial reliability difficulties with aircraft after they come back from long stays at the depot, and the experience with BF-37 onboard USS *Wasp* would support these observations.
- Poor fuel system reliability proved particularly challenging, in part due to the nature of the shipboard environment. The detachment experienced two major fuel system failures, a fuel boost pump and a high level float valve. For fuel system maintenance, the aircraft must be drained of fuel and then certified gas-free of combustible fuel vapors before work can proceed. Onboard ship, this lengthy process must be done in the hangar bay and little work on other aircraft in the bay can occur, particularly

electrical work or hot-work, due to the risk of sparks igniting fuel vapors. This is less of an issue on land, where the aircraft can be moved far away from other aircraft while de-fueling. The Marines decided to fly one of these aircraft on a one-time waiver back to shore and swap it with a replacement aircraft in order to keep flying, and not over-burden maintenance. However, this would not be an option when deployed in a combat zone. The program should increase fuel system reliability, especially for the F-35B and F-35C variants.

- The detachment staged all necessary personnel, support equipment, tools, and ship's facilities to conduct engine and lift-fan removals and installations in the hangar bay, but did not actually conduct any, as a basic fit-check. The amount of space required for this heavy propulsion maintenance is substantial and could have a significant operational impact on ACE operations when far more aircraft are present in the hangar bay and on the flight deck.
- During the underway period, the Marines successfully delivered a mock spare F-35 engine power module to the USS *Wasp* via internal carry on an MV-22 tilt-rotor, and returned it back to shore. This concept demonstration opens up a potentially viable re-supply method for the F-35 engine power module, which is too large and heavy to deliver to a ship at sea using current, traditional replenishment methods. Work remains to be done to ensure that this method will not damage spare engine modules but, if successful, will ease logistical support of F-35's while onboard ship.
- Ordnance evolutions included uploading and downloading of inert AIM-120 missiles, and GBU-12 500-pound laser guided and GBU-32 1,000-pound Global Positioning System-guided bombs. In order to load the bombs to their appropriate stations in the internal weapons bay, the station had to be disconnected from the aircraft, lowered and coupled to the bomb, and then re-connected to the aircraft with the bomb attached. This procedure potentially invalidates pre-ordnance loading checks to ensure that the weapons stations are working properly (i.e., that they will provide appropriate targeting information to the weapon and release the weapon when commanded).
- The lack of production-representative support equipment prevented the detachment from providing cooling air on the flight deck, which is necessary to prevent the avionics from overheating while conducting maintenance and servicing while on external electrical power or internal battery power. This limited the ability to troubleshoot on the flight deck and made refueling operations less efficient. The program should demonstrate regular flight deck operations with the intended operational support equipment before an actual combat deployment.
- The program conducted several tests with a Handheld Imaging Tool (HIT) that uses a small radar to scan the aircraft and determine its degree of stealth. The HIT can be used to scan for areas where the Low Observable (LO) material needs to be repaired, as well as to verify repairs to LO materials. It is a replacement for a previous Radar Verification Radar, which was too large for efficient use in the crowded hangar bay of an aircraft carrier. Initial results of the HIT testing looked very promising, although further developmental work remains.
- Several other important findings surfaced from the USS *Wasp* demonstration:
  - When the aircraft is on jacks in the hangar bay, maintainers must securely tie it down to the deck with chains to ensure that the ship's rocking motion in the waves does not cause the aircraft to slip off. However, the tie down pattern used prevented the weapons bay doors from being opened while the aircraft is on jacks. This will prevent maintainers from connecting cooling air, since the intake port is located in the internal weapons bay, and may limit efficient completion of landing gear maintenance.
  - With the current software configuration, when maintainers apply external power to the aircraft, the anti-collision strobe lights come on automatically, flashing for a few seconds until maintainers can manually turn them off. This violates ship light's discipline, and at night, it can briefly blind flight deck personnel as well as potentially reveal the ship's position. The program must change the software to prevent this occurrence onboard ship.
  - The L-class ships currently lack the facilities to analyze any debris found on magnetic chip collectors in the engine oil system. Metal shavings in the engine oil could indicate that engine components such as bearings may be wearing out, which could cause the engine to seize in flight. Currently, if maintainers discover chips, they will have to down the aircraft and mail them out to a shore facility that can analyze the shavings to determine if the engine is up, or requires particular maintenance. This process could take several days.
  - When the aircraft is wet it is extremely slippery. The F-35 sits higher off the deck than legacy aircraft so falls off of it can cause greater injury, or at sea, can lead to a man-overboard. This is exacerbated by the plastic booties maintainers are supposed to wear when working on the aircraft to protect the LO coatings. The detachment decided, for safety reasons, to allow maintainers to work on the aircraft without wearing these booties. The program should investigate alternate footwear to continue to protect aircraft LO coatings while also ensuring the safety of maintainers.
  - When aircraft were landing nearby, the Maintenance Interface Panel door vibrated alarmingly. The maintainers have this door open in order to plug in their portable computers to get information from the aircraft and control it while conducting servicing and maintenance. The Marines resorted to assigning a maintainer to hold the door, while another worked on the computer if flight operations were ongoing nearby.

This was an inefficient use of manpower, and the door hinge should be stiffened to withstand the flight deck environment.
- The Navy made several modifications to the USS *Wasp* in order to support F-35B operations. The deployment demonstration provided the following observations on some of these ship modifications:
  - Naval Sea Systems Command installed a Lithium-Ion battery charging and storage facility. The F-35 relies on 270 Volts-Direct-Current and 28 Volts-Fully-Charged Lithium-Ion batteries, and other assets that will deploy onboard L-class ships are also predicted to make greater use of Lithium-Ion batteries. However, Lithium-Ion batteries can catch fire under certain circumstances, especially during charging and, due to their chemical nature, cannot be extinguished but must burn themselves out. The storage facility consisted of racks of lockers that resembled ovens, each with its own exhaust system that could flue smoke and heat from a battery undergoing "thermal runaway." Battery charging would occur only in these lockers. Despite a flaw relating to the facility's air conditioning system being installed improperly, the general design appeared robust and functional.
  - F-35 pilots must conduct much of their mission planning inside a Special Access Program Facility, a vault-like room that is protected against electronic eavesdropping and is highly secure. The Navy installed a small Special Access Program Facility to house several classified ALIS components and provide an area for pilot briefings and debriefings. This facility was adequate for the demonstration, but was stretched to capacity to support a six F-35B detachment. The Navy and Marine Corps are investigating concepts for equipping L-class ships with JSF "heavy" ACEs consisting of 16 to 20 F-35B's. In these cases, a much larger facility would be required.
  - The Navy applied a high-temperature coating called Thermion to the flight deck spots where F-35B aircraft will land, in lieu of the traditional "non-skid" coating, to withstand the F-35B's exhaust, which is hotter than the AV-8B. One week into flight operations, personnel noted several chips of the first of two layers of Thermion were missing along a weld seam and started monitoring the site after each landing. No further degradation of the Thermion was noted for the rest of the detachment. Naval Sea Systems Command is analyzing the performance of the coating.

F-35C

- The second phase of ship suitability testing—DT-2—was conducted from October 2 – 10, 2015. Ship availability delayed the start of DT-2 from the planned date in August 2015. The principal goal of DT-2 was to perform launch and recovery of the F-35C with internal stores loaded.
  - The F-35C sea trials are a series of developmental tests conducted by the program with the principal goal of supporting development of the aircraft launch and recovery bulletins, and the general goal of characterizing ship suitability for operating and maintaining F-35C on a CVN-class ship. During DT-2, only developmental test aircraft CF-3 and CF-5, transient aircraft needed for logistical support, and search and rescue helicopters deployed to the carrier. No air wing was present. The major contractor was responsible for maintenance. ALIS was not installed on the carrier; it was accessed via satellite link to a location ashore.
  - Testers accomplished 100 percent of threshold and objective test points (280 total test points) over the course of 17 flights totaling 26.5 flight hours. The results of the test are still in analysis. In addition to the principal goal, the test points addressed:
    - Minimum end airspeed for limited afterburner and military power catapult launches. For catapult launches that use afterburner, engine power is initially limited to less than full afterburner power while the aircraft is static in the catapult, but then automatically goes to full afterburner power once released. This power limitation was in place to reduce thermal loads on the Jet Blast Deflectors (JBDs) behind the aircraft.
    - Crosswinds catapults
    - Recovery in high headwinds
    - Initial Joint Precision Approach and Landing System testing
    - Qualities of the Gen III HMDS at night
    - Running the Integrated Power Package (IPP) and engine in the hangar bay
    - Engine and power module logistics in the hangar bay
  - There were 7 bolters (failure to catch an arresting wire) in 66 arrestments during DT-2. During DT-1 (Developmental Test – One), there were no unplanned bolters in 122 arrestments. The higher rate was expected since the carrier arresting gear was not fully operational during DT-2. The third arresting wire (i.e., the wire typically targeted in carrier landings), was removed from service during the test because of a malfunction.
  - Testers ran the aircraft's IPP, a miniature gas turbine engine that can provide ground power, in the hangar bay. They then performed a low-thrust engine run as well. This process simulated maintenance checkout procedures that frequently occur in the hangar bay with legacy aircraft. During these evolutions, crew position the aircraft with its tail pointing out of one of the set of hangar bay doors to the aircraft elevators to direct heat and exhaust away from the inside of the ship. For the F-35C, the unique concern is that the IPP exhaust vents up towards the hangar bay ceiling. The test team monitored the IPP exhaust gas temperature to ensure it would not damage the ceiling of the hangar bay. During both the IPP run and the engine-turn, this temperature remained within safe limits. Testers also collected noise data; analysis is ongoing. The team did not collect data on the potential build-up of IPP exhaust gases within the hangar bay atmosphere, but plans to collect these data during DT-3.

- DT-3, the third and final set of sea trials, will expand the carrier operating envelope further, including external stores, and is scheduled to occur in August 2016.
- The Navy is working on the following air-ship integration issues, primarily for carriers. Some of the following issues also apply to F-35B operations on L-class ships:
  - Flight deck JBDs may require additional side panel cooling in order to withstand regular, cyclic limited afterburner launches from an F-35C. JBDs are retractable panels that re-direct hot engine exhaust up and away from the rest of the flight deck when an aircraft is at high thrust for take-off. Even with this additional cooling, however, JBDs may be restricted in how many consecutive F-35C limited afterburner launches they can withstand before they will require a cool down period, which could affect the launch of large "alpha strikes" that involve every aircraft in the air wing, a combat tactic the Navy has used frequently in past conflicts. F-35C limited-afterburner launches are required when the F-35C is loaded with external weaponry and in a heavy, high-drag configuration. The Navy estimates that an F-35C will have 3,000 catapult launches over a 35 year expected lifespan, but that no more than 10 percent of these launches will be limited-afterburner.
  - The Navy continues to investigate the replacement of a mobile Material Handling Equipment crane for several purposes onboard carriers, including, and perhaps most importantly, facilitating F-35 engine module maintenance. In order to transfer spare F-35 engine modules from their containers onto a transportation trailer, so they can later be installed in an aircraft, or to take broken modules from a trailer and put them into a shipping container to send back to an ashore repair site, a heavy lift capable crane is required. Onboard L-class ships, the Navy will use an overhead bridge crane built into the hangar bay ceiling, but CVNs do not have any similar ship's facility and the Navy intends to use a mobile crane. However, efforts to acquire a suitable crane have gone more slowly than originally expected. Given procurement timelines, the Navy must proceed without any further delays in order to have an appropriate crane onboard ship in time for the projected first deployment of an F-35C.
  - Work continues on developing triple hearing protection for flight deck crews, but with little update since the FY14 DOT&E Annual Report. Both the F-35C and F/A-18E/F produce around 149 decibels of noise where personnel are normally located when at maximum thrust during launch evolutions. The Navy has determined that 53 decibels of attenuation will be required from a triple hearing protection system to allow these personnel to be on deck for 38 minutes, or the equivalent of 60 launch and recovery cycles. Current designs only achieve in the mid-40s decibel range of attenuation, which allows less than 10 minutes of exposure before certain flight deck personnel reach their maximum daily limit of noise.
  - Two methods of shipboard aircraft firefighting for the F-35 with ordnance in the weapons bay are being developed, one for doors open and one for doors closed. Each will consist of an adapter that can fit to the nozzle of a standard hose. The open door adapter will also attach to a 24-foot aircraft tow bar so firefighters can slide it underneath the aircraft and spray cooling water up into the bay.
    - The Navy has produced four articles of the open bay firefighting device. This adapter performed well in preliminary tests conducted in 2014. Three of the production articles have been sent to Naval Air Station China Lake for further evaluation, and the fourth has been sent to a training command at Naval Air Station Norfolk to begin training flight deck personnel in its use and ship's company personnel how to maintain it.
    - Developmental work continues on the closed bay adapter. The Navy is currently pursuing two different designs that would cut through the aircraft skin to flood the weapons bay with water as well as lock into place to allow firefighting crews to back away from the fire after the hose is securely attached to the aircraft. One design will require two sailors to use, and the other design is more aggressive, but would potentially only require a single sailor.

Climatic Lab Testing

- The program conducted climatic testing on an F-35B test aircraft (BF-5) in the McKinley Climatic Laboratory from October 2014 to March 2015. All the planned environments were tested, but logistics tests (low observable repair and weapon loading, for example) were not completed due to delays that occurred in test execution.
- Testing of timelines to meet alert launch requirements showed start-up to employment capabilities (both air-to-air and air-to-ground) exceeded the ORD requirements (i.e., took longer than required), in some cases up to several minutes. Cold alert launches performed better than predicted (and in some cases met requirements), while hot launch times were worse than predicted. The program has no plan to address these requirements during SDD.
- The program did not fully test some necessary functions, such as landing gear operations. Additionally, some major production support equipment was not available for testing. Portable enclosures for low-observable restoration did not meet expectations. The program has an additional test period planned for February 2016 using an operational aircraft.

Cybersecurity Operational Testing

- In accordance with DOT&E and DOD policy, the JOTT developed and presented a cybersecurity operational test strategy to DOT&E for approval in February 2015. This strategy established a schedule and expectations for cybersecurity testing of the JSF air system through the end of SDD and IOT&E in late 2017. The strategy includes multiple assessments aligned with the blocks of capability as

the program delivers them to the field in both the air vehicle and ALIS. The test teams will conduct the assessments on fielded, operational equipment. All testing requires coordination from the JSF Program Executive Officer, via an Interim Authority to Test (IATT). This testing is OT&E; DOT&E approves the plans and independently reports results. The test strategy approved by DOT&E includes end-to-end testing of all ALIS components and the F-35 air vehicle.
- The Navy conducted a Cooperative Vulnerability and Penetration Assessment (CVPA) of the ALIS Squadron Kit 2.0.0.2 aboard the USS *Wasp* from May 26 through June 15, 2015. Findings were mostly administrative in nature and the test team recommended changes to the procedures for updating antivirus signatures, system restoral, and issuing user IDs and passwords prior to systems becoming operational at deployed or ship-based locations.
- Starting in early CY15, the JOTT began planning CVPAs and Adversarial Assessments (AA) of all ALIS components in the latest configuration to be fielded—ALIS 2.0.1.1—as well as the F-35 air vehicle in the Block 2B configuration. Consistent with the strategy, the JOTT planned a CVPA for September 21 through October 2, 2015, and an AA for November 9 – 20, 2015. Only the ALIS components were to be tested in these events, with an air vehicle to be included in a future test event. However, the test teams were not able to complete the CVPA as planned due to the failure of the Program Office to provide an IATT. According to the Program Office, an IATT was not granted due to insufficient understanding of risks posed to the operational ALIS systems by cybersecurity testing. As a result, the Program Office directed a more thorough risk assessment and restoration rehearsals on the ALIS systems undergoing testing to improve confidence in the identified risk mitigations.
- To recover progress on the test strategy, the JOTT coordinated with cybersecurity test teams for the November 2015 AA to be combined with a CVPA. However, the program approved only a partial IATT, which allowed a CVPA of the ALIS components at Edwards AFB and a CVPA of the Operational Central Point of Entry (CPE)—a major network hub in the overall ALIS architecture—to proceed. Although authorized, the AA for the CPE was not accomplished as the IATT was not provided in time for the AA team to make arrangements for the test. Although significantly limited in scope relative to original plans, the testing nonetheless revealed significant cybersecurity deficiencies that must be corrected.
- An end-to-end enterprise event, which links each component system, including the air vehicle, is required for cybersecurity operational testing to be adequate. The test teams are developing the needed expertise to conduct a technical vulnerability and penetration test of the air vehicle avionics and mission systems. Laboratory simulators at the U.S. Reprogramming Lab (USRL) and Lockheed Martin might be suitable environments for risk reduction and training, but will not take the place of testing on the vehicle. The Air Force Research Laboratory recently published an F-35 Blue Book of potential operational vulnerabilities that should help scope future air vehicle operational testing. The Program Office should accelerate the actions needed to enable cybersecurity operational testing of the fielded Block 2B and Block 3i systems that includes both ALIS and the air vehicle.
- The program plans to develop an ALIS test laboratory, referred to as the Operationally Representative Environment, to support developmental testing and risk reduction in preparation for future operational testing. This venue should be made available for cybersecurity testing as well, but will likely not be an adequate venue for cybersecurity testing for IOT&E.

Pilot Escape System

- In 2011, the program and Services elected to begin training and flight operations at fielded units with an immature pilot escape system by accepting risks of injury to pilots during ejection. These risks included pilots flying training missions with ejection seats that had not completed full qualification testing and flying overwater without the planned water-activated parachute release system (a system which automatically releases the parachute from the pilot's harness upon entry into water). Certain risks are greater for lighter weight pilots. Recent testing of the escape system in CY15 showed that the risk of serious injury or death are greater for lighter weight pilots and led to the decision by the Services to restrict pilots weighing less than 136 pounds from flying the F-35.
- Two pilot escape system sled tests occurred in July and August 2015 that resulted in failures of the system to successfully eject a manikin without exceeding neck loads/stresses on the manikin. These sled tests were needed in order to qualify the new Gen III HMDS for flight release.
  - A sled test in July on a 103-pound manikin with a Gen III helmet at 160 knots speed failed for neck injury criteria. The program did not consider this failure to be solely caused by the heavier Gen III helmet, primarily due to similarly poor test results having been observed with Gen II helmet on a 103-pound manikin in tests in 2010.
  - The sled test was repeated in August 2015 using a 136-pound manikin with the Gen III helmet at 160 knots. This test also failed for neck injury criteria. Similar sled testing with Gen II helmets in 2010 did not result in exceedance of neck loads for a 136-pound pilot.
- After the latter failure, the program and Services decided to restrict pilots weighing less than 136 pounds from flying any F-35 variant, regardless of helmet type (Gen II or Gen III). Pilots weighing between 136 and 165 pounds are considered at less risk than lighter weight pilots, but at an increased risk (compared to heavier pilots). The level of risk was

labeled "serious" risk by the Program Office based on the probability of death being 23 percent and the probability of neck extension (which will result in some level of injury) being 100 percent. Currently, the program and the Services have decided to accept the risk to pilots in this weight range, although the basis for the decision to accept these risks is unknown.

- The testing showed that the ejection seat rotates backwards after ejection. This results in the pilot's neck becoming extended, as the head moves behind the shoulders in a "chin up" position. When the parachute inflates and begins to extract the pilot from the seat (with great force), a "whiplash" action occurs. The rotation of the seat and resulting extension of the neck are greater for lighter weight pilots.
- The Gen III helmet weighs 5.1 pounds, approximately 6 ounces more than the Gen II helmet. The increased weight is primarily due to the larger/heavier night vision camera optics. The program has a weight reduction project ongoing to determine if approximately 5 ounces can be eliminated in the Gen III helmet by reducing structure and materials without affecting fit or optics.
- In coordination with the Program Office, the ejection seat contractor funded a proof-of-concept ejection sled test in October to assess the utility of a head support panel (HSP), a fabric mesh behind the pilots head and between the parachute risers, to prevent exceeding neck loads during the ejection sequence for lighter weight pilots. Based on the initial results, the Program Office and Services are considering seat modifications that would include the HSP, but they may take up to a year to verify improvement and install them onto aircraft.
- Additional testing and analysis are also needed to determine the risk of pilots being harmed by the transparency removal system (which shatters the canopy before, and in order for, the seat and pilot to leave the aircraft) during ejections in other than ideal, stable conditions (such as after battle damage or during out-of-control situations).
- The program began delivering F-35 aircraft with a water-activated parachute release system in later deliveries of Lot 6 aircraft in 2015. This system, common in current fighter aircraft, automatically jettisons the parachute when the pilot enters water after ejection and is particularly beneficial if the pilot is incapacitated at this point.

Progress in Modification of LRIP Aircraft

- Modification of early production aircraft is a major endeavor for the program, driven by the large degree of concurrency between development and production. Modifications are dependent on the production, procurement, and installation of modification kits, completed either at the aircraft depot locations or at the field units. If early production aircraft are to be used for IOT&E, as has been planned, the program will need to modify them in order to provide production representative Block 3F operational test aircraft for an adequate IOT&E. Current projections by the Program Office show that, even with accelerated contracting, the operational test fleet will not complete modifications until April 2019. This is 20 months past August 2017, the date currently planned by the Program Office for the start of IOT&E.
- The program maintains a complex modification and retrofit database that tracks modifications required by each aircraft, production break-in of modifications, limitations to the aircraft in performance envelope and service life, requirements for additional inspections until modifications are completed, and operational test requirements and concerns.
  - Major modifications take place at aircraft depots while depot field teams will travel to field unit to complete other modifications. Additional modifications will occur while aircraft undergo unit-level maintenance.
  - Some aircraft, primarily those assigned to operational test, will undergo modification first to a Block 2B and then to a Block 3F configuration, and will require two inductions to an aircraft depot for several months each.
- Upgrading F-35 aircraft to a Block 2B configuration includes modifications based on capability and life limits on hardware. Major modification categories include:
  - Structural life-limited parts, or Group 1 modifications
  - F-35B Mode 4 operations, including a modification to the Three Bearing Swivel Module (3BSM) so F-35B aircraft can conduct unrestricted Mode 4 operations
  - On-Board Inert Gas Generation System (OBIGGS), which provides the upgraded hardware for generating adequate nitrogen-enriched air to support lightning protection requirements and reduce vulnerability to fuel tank explosions from a live fire event; however, the aircraft will need additional modifications to the fuel system for full lightning and vulnerability protection
  - Upgrades to ALIS and training systems
- During the first half of 2015, Marine Corps IOC aircraft received top priority for Block 2B modifications. During the second half of 2015, the program prioritized modification of operational test aircraft.
  - To successfully modify Marine Corps aircraft in time for IOC, and because aircraft modifications frequently took longer than projected, the program, for the first time, sent Marine Corps aircraft to the Air Force depot at Hill AFB.
  - Because of the re-scoping of the Block 2B operational testing, the program delayed modifications to a number of aircraft assigned to operational test squadrons. As of December 2015, 8 of 14 aircraft assigned to operational test squadrons were in the full Block 2B configuration, which includes the OBIGGS modification, with 1 more undergoing depot modifications. One F-35B is not scheduled to complete this modification until June 2017. Twelve of the 14 aircraft have been at least partially modified to the Block 2B configuration, allowing them to fly with the Block 2B software.

- Modifying aircraft to a Block 3F configuration includes completing Block 2B modifications, Technical Refresh 2 (TR-2) upgrades, and Block 3F changes. The table below shows known requirements by production lot of aircraft and the number of those that are authorized and scheduled as of July 2015. Later lots of aircraft require fewer modifications because of changes incorporated into the production line.

KNOWN BLOCK 3 IOT&E MODIFICATION REQUIREMENTS IN LOTS 3 THROUGH 9[1]							
Variant	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9
F-35A	124 (69)	100 (44)	83 (32)	38 (15)	15 (2)	10 (1)	2 (1)
F-35B	130 (77)	106 (56)	82 (38)	38 (19)	10 (2)	3 (0)	1 (0)
F-35C	-	96 (43)	80 (30)	38 (15)	14 (2)	8 (1)	2 (0)

1. Numbers in parentheses denote authorized and scheduled modifications.

- Current Program Office plans for modifications show that none of the operational test aircraft will have all Block 3F modifications completed by the Program Office's projected start of IOT&E in August 2017.
  - The program awarded an undefinitized contract action (UCA) for new TR-2 processors in September 2015 to support Block 3F retrofit modifications of the Block 2B operational test aircraft. However, the TR-2 hardware packages have a 26-month lead-time which, along with other required changes that do not yet have approved engineering or hardware solutions, will delay the complete modification of any operational test aircraft until after IOT&E is scheduled to start.
  - The program is analyzing options to reduce this timeline, including seeking authorization outside of normal acquisition practices to purchase hardware early, taking components from the production line before installation occurs for use on operational test aircraft, and installing instrumentation on later LRIP aircraft that will have already received this hardware during production.
  - The majority of aircraft assigned to operational test squadrons are LRIP 3 and 4 aircraft, which require extensive modifications to reach a Block 3F configuration.
- The program has had difficulty maintaining the planned induction schedule at the two F-35 depots located at MCAS Cherry Point, North Carolina, and Hill AFB, Utah, after structural modifications took 20 days longer than planned on early inductees, and Lockheed Martin delivered modification kits late. Transportation issues also resulted in retrograde assets not shipping in a timely manner for repairs and upgrades.
  - At MCAS Cherry Point, early F-35B aircraft inducted took 45 days longer than projected to complete modifications and, as of July 2015, the depot had used nearly 300 more cumulative maintenance days than projected to modify aircraft. To meet Marine Corps IOC requirements, the program sent two aircraft, BF-31 and BF-32, to Hill AFB to complete structural modifications. Prior to this, the program had not scheduled F-35A or F-35B aircraft to complete modifications at the other Service's depot. As of June 2015, the MCAS Cherry Point depot completed modifications on 16 aircraft, 5 of which the program needed for Marine Corps IOC.
  - The Hill AFB depot has stayed closer to projections on completing modifications. Although early inductees exceeded the planned timeline, later aircraft, including the two F-35B aircraft, have completed modifications in less time than projected. Fourteen aircraft have completed modifications at this depot, including two F-35B aircraft needed for Marine Corps IOC. Hill AFB, which began the year with three operational docks, expanded their depot capacity to eight docks in 2015 by accelerating the opening of four of these docks to reduce the risk of maintaining the modification schedule.
  - The program further reduced risk to the modification schedule by employing additional field teams to complete modifications previously planned to occur during aircraft inductions.
  - By July 2015, both depots showed improved tracking with the depot flow plan.

Recommendations

- Status of Previous Recommendations. The program addressed two of the previous recommendations. As discussed in the appropriate sections of this report, the program did not, and still should:
  1. Update program schedules to reflect the start of spin-up training for IOT&E to occur no earlier than the operational test readiness review planned for November 2017, and the associated start of IOT&E six months later, in May 2018.
  2. Complete lab testing of the mission data loads, as is planned in the mission data optimization operational test plan, prior to accomplishing the necessary flight testing to ensure the loads released to the fleet are optimized for performance. If mission data loads are released to operational units prior to the completion of the lab and flight testing required in the operational test plan, the risk to operational units must be clearly documented. Status: Lab testing in Block 2B is still in work; 2B build fielded to operational F-35B units, risk not documented.
  3. Complete the remaining three Block 2B weapon delivery accuracy (WDA) flight test events in a way that ensures full mission systems functionality is enabled in an operationally realistic manner.
  4. Provide adequate resourcing to support the extensive validation and verification requirements for the Block 3 VSim in time for IOT&E, including the data needed from flight test or other test venues.
  5. Extend the full-up system-level (FUSL) decontamination test to demonstrate the decontamination system effectiveness in a range of operationally realistic

environments. Status: The Program Office has elected not to address this recommendation: the FUSL test will be conducted only under ambient conditions at Edwards AFB during 4QFY16 through 1QFY17 preventing the assessment of this system in other, potentially more stressing ambient conditions.

6. Ensure adequate testing of ALIS software upgrades on operationally-representative hardware is complete prior to fielding to operational units.

- FY15 Recommendations. The program should:
  1. Acknowledge schedule pressures that make the start of IOT&E in August 2017 unrealistic and adjust the program schedule to reflect the start of IOT&E no earlier than August 2018.
  2. The Department should carefully consider whether committing to a “block buy,” composed of three lots of aircraft, is prudent given the state of maturity of the program, as well as whether the block buy is consistent with a “fly before you buy” approach to defense acquisition and the requirements of Title 10 United States Code.
  3. Plan and program for additional Block 3F software builds and follow-on testing to address deficiencies currently documented from Blocks 2B and 3i, deficiencies discovered during Block 3F developmental testing and during IOT&E, prior to the first Block 4 software release planned for 2020.
  4. Significantly reduce post-mission Ground Data Security Assembly Receptacle (GDR) processing times, in particular, decryption processing time.
  5. Ensure the testing of Block 3F weapons prior to the start of IOT&E leads to a full characterization of fire-control performance using the fully integrated mission systems capability to engage and kill targets.
  6. Complete the planned climatic lab testing.
  7. Provide the funding and accelerate contract actions to procure and install the full set of upgrades recommended by DOT&E in 2012, correct stimulation problems, and fix all of the tools so the U.S. Reprogramming Lab (USRL) can operate efficiently before Block 3F mission data load development begins.
  8. Complete the planned testing detailed in the DOT&E-approved USRL mission data optimization operational test plan and amendment.
  9. Along with the Navy and Marine Corps, conduct an actual operational test of the F-35B onboard an L-class ship before conducting a combat deployment with the F-35B. This test should have the full Air Combat Element (ACE) onboard, include ordnance employment and the full use of mission systems, and should be equipped with the production-representative support equipment.
  10. Develop a solution to address the modification and retrofit schedule delays for production-representative operational test aircraft for IOT&E. These aircraft must be similar to, if not from the Lot 9 production line.
  11. Provide developmental flight test tracking products that clearly show progress on what has been accomplished and test activity remaining.
  12. Develop an end-to-end ALIS test venue that is production representative of all ALIS components.
  13. Ensure the necessary authorizations are provided in time to permit operational cybersecurity testing of the entire F-35 air system, including the air vehicle, as planned by the operational test community.
  14. Provide dedicated time on representative air vehicles to complete Joint Technical Data (JTD) verification.